Experience with Traffic Actuated Signals

ERIC G. THORSON
District Traffic Signal Engineer
Illinois Division of Highways
Elgin, Illinois

The State of Illinois installed its first set of traffic actuated signals in August 1935. Since that time the number of installations of this type has increased to a total of 276 as of February 1955. We also have 38 installations of fixed-time signals. In 1954 we had 67 traffic actuated installations under contract. Most of these were installed in 1954, however a few were held over to this year because of winter. All but approximately 25 of our installations are located in Districts 1 and 10. District 10 comprises Cook County and District 1 includes eight counties surrounding Cook County. Naturally most of our signalized intersections would be located in this area because of the high traffic volumes around the city of Chicago.

The reason for using traffic actuated signals is that they provide more efficient control of traffic than fixed-time signals in that the cycle will vary with the demand, within limits. These limits will be described later when we take up the different types of controllers. The traffic actuated signal with this variable cycle is desirable where there is a wide variation in volumes of vehicles, and especially desirable where there is a wide variation in the ratio of volumes on opposing streets. I believe you will agree with me that it would be impossible to set up a fixed-time cycle to handle traffic efficiently in a rural area. With fixed-time signals you will stop traffic a large percentage of the time when there is no opposing traffic, which is not so bad within a municipality, but in a rural area you would be inviting disrespect for signals. With traffic actuated signals, a vehicle will be stopped only if there is opposing traffic traveling through the intersection.

Another item in favor of traffic actuated signals is that there is no need for a flashing indication during periods of low traffic volumes. In Illinois we have a requirement that traffic signals must be changed to a flashing indication when the volume of traffic through the intersection falls below 500 vehicles per hour. This flashing indication would show a yellow indication to the main street traffic and a red indication to cross street traffic. This requirement is not necessary with traffic actuated signals as the right of way will remain on the main street indefinitely, as long as there is no actuation on the cross street. It is for this reason that we are trying to promote traffic actuated signals within municipalities of small population and on the outskirts of large municipalities when we give them authority to install signals on our marked routes.

TRAFFIC ACTUATED CONTROLLERS

We use a few different types of traffic actuated controllers. The majority of our installations are the full actuated type with detectors located on all four legs of the intersection. Approximately 5% of our traffic actuated installations are the semi-actuated type with detectors located only on the cross street. About the same percentage are the full actuated volume density type. To fully understand the examples of signalized intersections I am going to discuss, I am first going to describe each type of controller that we use and the dial settings that regulate the timing.

The full actuated controller is designed for use with detectors on all legs of the intersection. It has five dial settings and a recall switch for each street, thus an intersection of two streets would have two sets of timing dials and two recall switches.

The first dial setting is the *Initial Interval.*

The Initial Interval is an extra period of time given at the start of the green period in order to permit waiting traffic to get into motion thus making possible the use of a short vehicle interval. Waiting cars do not all start immediately when the right of way is given to them but each car gets into motion about one second after the car ahead starts. With normal location of detectors there may be four or five cars between the stop line and the detector, consequently, four or five seconds will elapse before a car just in front of the detector gets into motion and one or two seconds more are required for this car to accelerate to normal speed. An initial interval of five to seven seconds is therefore ordinarily used but if there is an upgrade to the intersection on the approach involved it is often advisable to increase the initial interval somewhat to care for the longer time required for cars to get in motion. Whenever it is necessary to lengthen the green light interval to permit pedestrians to cross a wide street, the additional time should be inserted in the initial interval and not the vehicle interval.

The second dial setting is the *Vehicle Interval.*

The Vehicle Interval is the time allowed for a car approaching on a green light at average speed to travel from the detector to the intersection. This interval determines how much of a gap between successive cars will be required to yield the right of way to opposing waiting traffic and the efficiency of the controller depends largely on the proper timing of this interval. In general the efficiency of the controller is increased as the vehicle interval is shortened, as long as a car moving at average speed has sufficient time to pass from the detector to the intersection before the yellow signal comes on. The last moving car should finish its passage through the intersection on yellow not on green. A typical setting for this dial is about six or seven seconds.

The third dial setting is the *Maximum Interval.*

The setting of the maximum interval dial determines the longest time it is possible for the traffic to hold the green light after a car has already registered a call on another phase. If the light is in initial or vehicle interval when a car registers a call, the maximum interval dial setting determines the length of time it is possible for traffic to hold the green light from the time of actuation on the other phase. Maximum settings of 30 seconds are often used at average intersections.

The fourth dial setting is the *First Change Interval or Green Yellow Interval.*

The setting of the green yellow interval determines the length of time the green yellow light remains on. The length of the green yellow interval depends upon the particular condition of the street. An average setting for this interval is about four seconds.

The fifth dial setting is the *Second Change Interval or Red Yellow Interval.*

The setting of the red yellow interval determines the length of time the red yellow light remains on. This interval is set as short as possible, which is about 1½ seconds.

The sixth dial is the *Recall Switch.*

The recall switch is used when there is a breakdown and a detector is not operating. It is also used if it is desirable to operate the signals as a semi-actuated control. When the recall switch for a selected street is in the "on" position, the controller automatically registers an actuation for this street as soon as it loses the right of way. The green light will therefore always be called back to this selected street. In the complete absence of traffic the green light will remain on the selected street.

At this point I should describe the double yellow sequence of operation that we use with a normal two street intersection. The complete cycle is divided into phase A and phase B and each phase is divided into three intervals, thus in a complete cycle there will be six separate intervals. The maximum length of time of intervals one and four will depend upon the maximum interval dial setting of each street assuming, of course, that there is a constant flow of traffic to extend these intervals to the maximum. If only one vehicle takes the right of way and there is actuation on the cross street, these intervals will be the sum of the initial interval plus one vehicle interval. Intervals two and five are the first change intervals for each street respectively. Intervals three and six are the second change intervals that we use to release vehicles that are stopped at the intersection.

A full traffic actuated controller can be expanded into a three phase operation when you have an intersection of three streets or if you wish to provide for a separate turning movement. An example of where a three phase control is used would be where you have a two street intersection that is exceedingly high in traffic volume and the left turns conflict with the straight through traffic. In this case, the signal heads are split so that the indications on each side of the signal head are independent of the other.

Semi-actuated controls are used where the main street carries a high volume of traffic and the cross street very little traffic. In this case detectors are installed only on the cross street. The right of way remains indefinitely on the main street until an actuation occurs on the cross street. A controller of this type will have the same dial settings for the cross street as the full actuated but only three dial settings for the main street. These three dial settings for the main street are: a minimum green interval, a first change interval, and a second change interval. The one great weakness in this type of controller is that one vehicle on the cross street can take the right of way from a platoon of vehicles on the main street under certain conditions. The main street minimum green interval determines the minimum length of time that the right of way must be shown to the main street. This interval is timed out after every transfer of right of way from the cross street to the main street; consequently, after this interval has timed out and there is actuation on the cross street the right of way will transfer to the cross street even though a platoon of vehicles is moving through the intersection on the main street.

The full actuated volume density control goes a step further than the full actuated control in that it constantly varies its own timing according to traffic demands, thus providing more efficient control. The underlying principle of volume density control is a constant process of balancing the demand on the street having the green light against the accumulating demand on the street having the red light.

INTERSECTIONS WITH SPECIAL PROBLEMS

Now I would like to describe a few intersections with special problems and show how we have tried to solve them. The first intersection is a T intersection on the south corporate limits of Joliet. The area around this intersection is industrial in nature, consequently, there is a high surge of traffic in the morning when workers are going to work and again when leaving for home in the evening. The main problem was that most of the morning surge of traffic had to make a left turn against high speed traffic coming in from the country. Before this intersection was signalized there were quite a few serious accidents between left turn and straight through movements. The intersection being rural in nature, we of course installed vehicle actuated signals. But what kind of sequence of operation could be used to eliminate this hazard? A three phase controller could be used providing for this left turn movement, however, we found that it could be done with a two phase controller by splitting the phase controlling the traffic involving the two movements. The left turn movement would be controlled by a left turn green arrow; but now the question was, should this movement come at the beginning of the phase or at the end? By putting the left turn movement at the end of the phase, they would be held while most of the straight through traffic cleared, however, the danger would still exist. We decided to put this left turn movement at the beginning of the phase which would allow them to begin this movement against opposing traffic that has stopped. The left turn green arrow is on only a short time but the habits of drivers are such that once this movement is started the entire group of left turn vehicles will clear before the straight through movement is allowed to begin. This method of solving the conflict between left turn and straight through movement does not mean that accidents would not occur, yet, it does mean that the accidents that do occur will be only minor.

The next case involves two intersections and shows how a semi-actuated control was used to solve the problem. One of the intersections is operating very well with four way stop control, and just west of this intersection is the other having just a small volume of traffic on the cross street, but enough to warrant a demand for access to the main street. Here again we have an industrial area along the main street meaning, of course, a high surge of traffic during certain parts of the day. The problem in this case was that during the periods of high traffic volume, vehicles would stack up from the four way stop intersection back through the second intersection making it impossible for the cross street traffic to gain access. Here was a problem of breaking the steady flow of traffic on the main street in order to give vehicles time to clear the four way stop intersection without stacking up back through the second intersection. In this case a semi-actuated control was installed but instead of putting the detectors on the cross street they were installed on the main street. By installing the detectors on the main street, the maximum length of time the main street could hold the right of way could be set on the controller. This maximum interval was set as long as possible but just short of the time required for vehicles to stack up from the four way stop and block the intersection. At the end of each main street maximum interval, the right of way is transferred to the cross street and held long enough for a sufficient number of vehicles on the main street to clear the four way stop intersection. Here is a case where transfer of right of way is given to the cross street even though no vehicles are waiting, nevertheless, without this control any vehicle waiting on the cross street would never gain access during these peak periods. Aside from the cross street traffic gaining access, the main problem was to interrupt the main street traffic to prevent blocking the intersection.

The next intersection concerns a private enterprise but it will show how a problem can be solved by merely adjusting the time intervals. We recently installed full actuated controls at an intersection where a gas station had just one access entrance on each street. After the signals were actuated, we received a complaint from the owner of the gas station that vehicles entering his station on one street could not exit on the other as traffic was so heavy at times that waiting vehicles were lined up back beyond his exit. In this case we found that by increasing the maximum interval we allowed enough vehicles to clear on each cycle that waiting vehicles did not stack up beyond his drive.

Another type of intersection with a special problem is where two detectors must be used on one leg of the intersection. An example of this type is where the intersection is located near a grade separation. In this case, it would be impossible to locate one detector to handle all vehicles approaching the intersection, consequently, two detectors are used wired in series. One detector is placed to take care of traffic approaching on the ramp and the other placed to handle traffic on the main part of the approach. Two detectors on one approach of an intersection are also used when another street intersects that approach between the detector and stop line. The second detector is placed on the side street to avoid double actuation by vehicles on the main part of the approach.

In the design of traffic actuated signals care must be taken in the location of the detectors so as to avoid false calls and still pick up all desired calls. In some cases, we must vary the distance of the detector from the stop line so as to avoid false calls. An example of this is where you have set the distance of the detector from the stop line only to find that it is in the entrance to a gas station. When a detector is moved, the detector on the opposite leg should also be moved an equal distance in order to balance the timing of the vehicle interval. In some cases, the detector distance from the stop line is changed so as to include vehicles exiting from an establishment. This change would, of course, mean decreasing the detector distance and is done only where the change is small.

TYPES OF DETECTORS

We have two types of detectors in use, the magnetic type and the pressure type. Most of our installations are with the magnetic type detectors. All of our installations under contract in the last few years have been with magnetic type detectors. We have found that the pressure type detectors must be very carefully installed if used in our area where we have snow plowing operations. We have also found that eventually the pavement around the pressure detector becomes chipped and broken and requires a great deal of maintenance. The magnetic detector is installed in a non-metalic conduit under the pavement and requires no pavement cutting. There is no direct contact with vehicles, consequently, no wear. The original cost of the two types of detectors is about the same, however, we have found that the magnetic type detector has been the most satisfactory.

You might be interested in a cost comparison between full actuated and fixed time signals. A standard full actuated installation will cost between $7,000 and $8,000. A standard fixed time installation will cost between $3,000 and $4,000. It can be said that the cost of a traffic actuated installation is approximately twice that of a fixed time installation.

In Illinois we have a standard "near right and far left" indication, thus we have signals on all corners of the intersection. In some cases, such as the T intersection, we may have only three standards, however, we still have the "near right and far left" indication.

We use all underground wiring. Cables cross roadways and entrances are installed in conduit. Cables are also installed in conduit wherever the cables would be in danger of being cut. In our installations, we do not allow splicing between the controller and signals nor between the controller and the detectors. All cables must be continuous runs. In most cases, we try to use a multiple conductor cable with enough conductors so that we have a spare. It is advisable to have a spare conductor as it is far cheaper to pay for a cable with more conductors than to install a new cable. Another advantage of installing spare conductors is that the signals can be put back in operation immediately.

MAINTENANCE

The maintenance of our traffic signals in Districts 1 and 10, where most of the traffic actuated signals are located, is on a contract basis with a private electrical contractor. We have found that maintenance by our own forces is not feasible due to lack of qualified, specially trained personnel. It would be impossible to efficiently maintain our signals with maintenance forces that change periodically. Maintenance of traffic signals on a contract basis will permit a contractor to specialize in this type of work. A contract will permit him to retain trained personnel and have special equipment to handle this work. In districts other than 1 and 10, there are not enough signalized intersections to warrant contract maintenance. In these districts spare controllers and lamps are kept in the district office for replacements. Knock-downs are handled by local electrical contractors at the discretion of the district engineer.

Our maintenance contract is set up on a unit price basis. The units in the contract are as follows:

1-Way signal heads
2-Way signal heads
3-Way signal heads
Vehicle actuated signal controls
Vehicle actuated signal controls (Under guarantee)
Pressure type detectors
Magnetic type detectors
Magnetic type detectors (Under guarantee)

Each of these units include servicing, maintaining, and patrolling; and servicing and maintaining all cables and appurtenances thereto.

The contract outlines just what is required in servicing and maintaining each unit, the materials and items that the contractor must supply, and what constitutes extra work. Extra work such as knock-downs are handled on a force account basis; that is, the actual cost of material, labor, and expense, to which 15% is allowed on labor and materials.