Advance Warning System with Advance Detection

Intersections with limited visibility, high speeds (55 mph and greater), temporary or newly installed intersections, or grade issues often need an advanced warning system (AWS). The AWS information prepares motorists for unexpected traffic conditions, and is therefore especially effective during the first several encounters.

Over time, however, drivers are prone to tune out this information because of its static nature. Another option employed in a number of state departments of transportation is adding intelligence to the AWS. This intelligence is used to provide the motorists with more information about the intersection they are approaching, and make the signal dynamic in order to increase its effectiveness over time.

This application note describes how to increase the effectiveness of the AWS by combining it with advance detection. Specifically, the benefits of using Long Range–Continuous Tracking Advance Detection (LR-CTAD) technology in a combined AWS/AD system will be reviewed. These benefits include:

- LR-CTAD can be mounted on the AWS pole to reduce the cost of structures and trenching.
- LR-CTAD can detect vehicle speed and ETA at distances up to 500 ft away in order to improve indirect protection of the decision dilemma zone.

This application note also stresses the importance of a short lead flash time (the time between onset of flashers and onset of yellow) to prevent drivers from trying to race the system. Please refer to the Wavetronix Application Note AN0001 for detailed information regarding the decision dilemma zone and LR-CTAD technology.

Figure 1 – AWS/AD Overview
**Advance Warning Systems**

To minimize the hazards of unprotected green termination, some agencies advocate the use of advance warning systems (AWS). Advance warning systems signal upstream drivers that a phase change interval is imminent or that the movement is now inactive. Alerted motorists are expected to prepare to stop. Agencies using AWS sometimes limit the posted approach speeds within their jurisdiction to about 45 mph in order to further reduce the hazard of the change period. However, AWS are not universally accepted. Many traffic officials point out that some drivers abuse the warning information by trying to race the system.

To discourage motorists from abusing advance warning information, advance warning systems with advance detection (AWS/AD) have been designed. With a combined AWS/AD system, traffic flow characteristics at an upstream location can be used to predict a time when the traffic stream within the decision conflict zone will be low-risk or risk-free. The onset of yellow is then scheduled to occur when the risk will be minimal.

Sometime before the onset of yellow, the advance warning system will activate its signals. The combined system is intended to send a clear message to motorists: if they see the active signal, they should expect to stop on red; whereas if they do not see an active signal, they should expect to clear the intersection. These systems can operate with a relatively short lead flash time in order to reduce the likelihood of motorists racing the system to beat the light.

Agencies that use any or all of these specialized systems sometimes have a warrant procedure that determines what types of intersection approaches need what type of system. The warrant guidelines are based upon variables like intersection type, traffic mix, grade issues and design speed. Isolated high-speed intersections may warrant a system type other than high speed intersections within a coordinated corridor. Similarly, rural intersections with a high percentage of truck traffic and high speeds may warrant a different type of system than isolated intersections within an urban environment.

Even when these warrant guidelines are in place, the proficiency of the signal technician or signal engineer plays a critical role in the success of the system. For example, signal technicians often select the window of opportunity in which the system operates by selecting the minimum and maximum green times.

**Clear Message**

If the AWS is designed properly it will send a clear message to the driver. In an AWS/AD system the flashers provide advance warning of the onset of yellow. Motorists that see the flashers activate should be sent the message that they need to prepare to stop; they should be discouraged from trying to race the system and beat the light. Alternately, motorists that do not see the flashers come on should be sent the message that they may proceed through the intersection.

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**Figure 2 – AWS Lead Flash Concept**

![AWS Lead Flash Concept Diagram](image-url)
This type of clear message can be achieved with gap management techniques that tightly synchronize the timing of the AWS flashers and the yellow light. This technique creates a safer gap by maximizing the likelihood of the gap occurring over the onset of a yellow light. Motorists trailing the gap should see the flashers come on, then, at about 5.5 seconds from stop bar, they should see the yellow light come on (even if they try to accelerate). Motorists leading the gap should not see the flashers activate and should be closer than 2.5 seconds from the stop bar at the onset of yellow, making it safely through the intersection.

In the example shown in Figure 2, the onset of flashers leads the onset of yellow by 3.5 seconds, and the AWS is looking for a safe gap in traffic from 5.5 to 9.0 seconds upstream of the stop bar. This represents a gap size of 3.5 seconds. The vehicle leading the gap (Vehicle A) is about 5.5 seconds from the stop bar at the onset of the flashers and 2.0 seconds from the stop bar at the onset of yellow. The vehicle trailing the gap (Vehicle B) is about 9.0 seconds from the stop bar at the onset of the flashers and 5.5 seconds from the stop bar at the onset of yellow. In this example, Vehicle A would make it safely through the intersection, while Vehicle B would be prompted—first by the flashers, then by the yellow light—to stop at the stop bar.

The synchronization between the AWS flashers and the signal light is essential because ultimately drivers give more obedience to the signal light. This system safely manages the gap, whereas systems that do not correctly manage the gap actually trap drivers in the decision dilemma zone. Over time, drivers lose confidence in this type of system. If the lead flash time is too large, drivers are prone to abuse the AWS system and try to beat the light.

**Enhanced Visibility**

In order to see the flashers come on, the AWS sign should be within a driver’s cone of vision for all lanes of the approach. Signs should be positioned far enough away from the stop bar that motorists have adequate time to respond after seeing the flashing lights.

Traditionally, the AWS sign is a diamond sign with flashing beacons. If this traditional sign is used, it can be more effective to put a sign on each side of the approach.

![Figure 3 - Flashing Beacon AWS Sign](image)

In some cases, it has proven effective to use an overhead blank-out sign. The benefit of an overhead blank-out sign is not only visibility, but also a measure of distinction. Drivers are less likely to confuse the blank-out sign with the type of AWS system where the flashers are always active.
Minimize Impact of Max Out

The AWS system is similar to other green extension systems in that it does not override the maximum green time programmed into the traffic controller. In other words, AWS systems are subject to max out. However, in the event of max out, AWS systems will still provide drivers upstream of the flashers with advance warning of the clearance interval. Since a gap was not found, these drivers may be in the decision dilemma zone at the onset of yellow, but they have been given advance warning and should be more prepared to make a safe decision. This type of advance warning is often crucial to drivers of commercial vehicles in order to avoid load spills, skidding and collisions.

Cabinet Configuration

In order to minimize the impact of high-speed max out, the system designer should increase gap-out opportunities by limiting the number of cases for which green extension is warranted. There are several ways to do this, including the use of speed thresholds. In addition, the designer should evaluate the splits and cycle lengths at the intersection. Are time-of-day, dynamic maximum green or volume-density options warranted?

The traffic cabinet is configured to drive the AWS flasher load. The flasher load is active when the phase is inactive. For example, if the AWS system extends green for phase 2, then the flashers will be active when phase 2 is inactive. This is accomplished using a control panel that inverts the phase 2 output to drive a flashing beacon circuit.

The signal light loads are driven using a trailing overlap. Overlaps are defined as customized outputs driven by one or more included phases. Typically, the included phases are sequential so that the green output “overlaps” the clearance interval between two included phases. However, with a trailing overlap, the overlap output is simply extended beyond the length of the phase output. The trailing overlap then also has its own yellow and red clearance times that then need to be programmed. In essence, a trailing overlap adds an unnamed phase that keeps the signal indication green for a fixed amount of time after the included phase output goes yellow. In this case, the fixed amount of time (green time of the trailing overlap) is recommended to be about 3.5 seconds.

The detector output channel from the SmartSensor is wired in like a loop amplifier rack card. The controller input extension time (or as an alternative phase passage time) can then be used to determine the amount of green extension once the sensor output goes inactive.

Sensor Programming and Timing

SmartSensor Advance and the traffic controller work together to detect a 3.5-second gap. A three-second phase passage time (or as an alternative, an input extension time) is programmed into the controller to ensure that the gap is at least as three seconds long. The three-second passage time is added to the duration of each vehicle call in order to detect the 3.5-second gap. Vehicles qualify to send in a call based upon range, speed and ETA criteria. The call will last only as long as the qualification criteria are met. In this case, the calls have been designed to be approximately 0.5 seconds in duration so that the size of the gap will be about 3.5 seconds. The flexibility of
SmartSensor Advance’s zone placement and zone filtering was used to design green extension for a range of approach speeds, not just a single design speed. Two zones were used: one for slower speed vehicles and another for higher speed vehicles.

Zone 1 was used to extend green for vehicles going from 1 mph to 45 mph. While the current posted speed limit is 40 mph, a large percentage of vehicles were going faster than this speed at the installation site. (An advisory speed of 35 mph is also posted.) It is anticipated that the 85th percentile speed is 45 mph or higher. The location of zone 1 was selected to be from 575 ft to 610 ft from the stop bar. Vehicles tracked by the radar through this 35-ft zone will extend green for about 0.5 seconds if traveling at 45 mph. One suggested adjustment to the current design is to reduce the number of vehicles that will extend green (increase gap-out opportunities) by increasing the lower speed threshold from 1 mph to 25 mph or faster.

Zone 2 was used to extend green for vehicles going 45 mph and faster. The location of zone 2 was selected to be from 600 ft to 1000 ft from the stop bar. Vehicles tracked by the radar through this 400-ft zone will extend green for about 0.5 seconds. The exact distances for which extension will occur depend upon the vehicle speed because ETA filtering from 8.7 to 9.2 seconds is employed. ETA criteria help synchronize the lead flash time so that high-speed vehicles will not be in the decision dilemma zone at the onset of yellow. For example, a vehicle traveling at 55 mph will send a call to the controller while it is traveling from 742 ft to within 702 ft of the stop bar. Likewise, a vehicle traveling at 70 mph will send a call to the controller while it is traveling from 946 ft to within 894 ft of the stop bar. This type of dynamic detection overcomes some of the limitations inherent with traditional fixed-point detection.

One suggested adjustment to the current design is to reduce the number of vehicles that will extend green (increase gap-out opportunities) by bringing the far edge of the zone in from 1000 ft to 950 ft. Vehicles traveling 70 mph or faster will still trigger the call with this adjustment (unless the higher speed filter is reduced from 100 mph), but the duration of the call may be less than 0.5 seconds since 70 mph is double the advisory speed at the installation site of 35 mph.

One last consideration for sensor programming and timing is the placement of the sign. With the sign positioned 500 ft from the stop bar, 45-mph vehicles trailing the gap will be just about 1.7 seconds upstream of the sign when the flashers turn on. High-speed vehicles that are trailing the gap will be even further upstream at the onset of the flashers. This should provide good visibility of the flashing beacons and adequate response time.