

# Advance Queue Detection and Queue Management

0046

Traffic engineers use storage queues as a tool to help manage the variability in vehicle flow and optimize system throughput. For example, at signalized intersections, accumulation of cross-street demand during red is used to help maximize the throughput during the subsequent green.

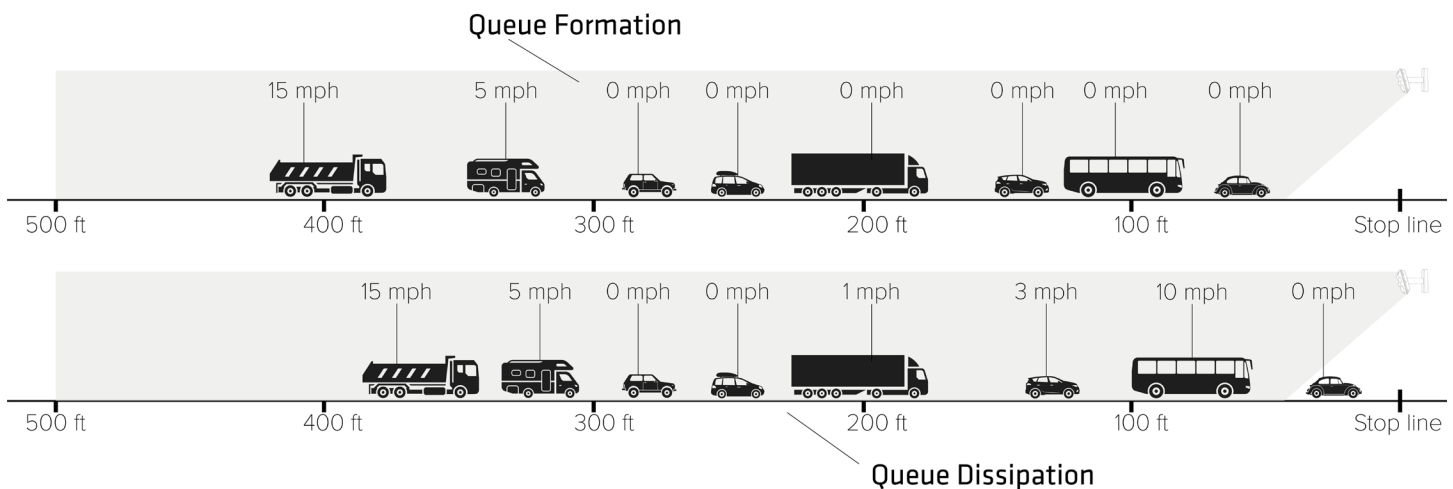
Additionally, in order to help coordinate arterial progression in tightly packed platoons, queuing at both inbound approaches on the extremities of a corridor is regulated. Or on freeway on-ramps, queuing is metered to prevent deterioration of flow along the freeway mainline.

SmartSensor Advance can detect vehicles up to 600 ft. (182.88 m) upstream or downstream of its mounting location, and the SmartSensor Advance Extended Range can detect semis and other large vehicles at a range of 900 ft. (274.32 m). The long-range detection capability makes it uniquely cost-effective for many queue detection applications. SmartSensor Advance is classified as a continuous tracking advance detector (CTAD), which means that it continuously tracks the speed, position and estimated time of arrival (ETA) of approaching vehicles.

## Queue Formation

At signalized locations, vehicle arrival rates fluctuate throughout the day and often from one signal cycle to the next. Because of the unpredictable variability, vehicle sensors are needed to maximize throughput and manage traffic on demand.

One way to detect the level of arriving traffic flow at an intersection is to count the number of vehicles. SmartSensor Advance can provide a good estimation of the number of vehicles that arrive during the red interval.



Another way to monitor queue levels is to program SmartSensor Advance to detect the drop in speeds when queue spillback has reached setback locations of interest. This method allows the ability to continuously activate different channels based on the estimated queue length.

A 2009 Ramp Queue Detection report conducted for Mn/DOT by SRF Consulting used four channels to estimate queue length in this way. Queue length was reported at points of interest 100, 200, 250, and 275 ft. (30.5, 61, 76.2, and 83.8 m) back from the flasher stop line. The study reported that the average error in queue length estimation

was 9.2 ft. (2.8 m) and the absolute average error was 36.1 ft. (11 m). These “excellent results” were achieved as the queue length on the ramp fluctuated from 0 to over 250 ft. (0 to 76.2 m) and back six times during the almost two-hour period from 3:15 to 5:00 p.m.

## Queue Dissipation

Motor vehicles form first-in-first-out queues. When these queues dissipate, vehicle speeds first rise near the front of the queue. In some applications, like ramp metering, only one vehicle exits the queue every three or more seconds and vehicle speeds never reach free-flow levels.

In other applications, like signalized arterial traffic flow, a large portion of the standing queue will reach free-flow speed during the green time. The table below presents the amount of time required for vehicles at incremental queue positions to reach the stop line on green.

Queue Position	Green Time
50 ft (15.2 m)	7 sec.
100 ft (30.5 m)	11 sec.
150 ft (45.7 m)	15 sec.
200 ft (61 m)	19 sec.
250 ft (76.2 m)	23 sec.
300 ft (91.4 m)	27 sec.
350 ft (106.7 m)	31 sec.
400 ft (121.9 m)	35 sec.
450 ft (137.2 m)	39 sec.
500 ft (152.4 m)	43 sec.

For example, if a vehicle is stopped 500 ft (152.4 m) from the stop line at the start-of-green, it will be about 43 seconds before that vehicle reaches the stop line.

## Queue Channel Configuration

How a SmartSensor Advance queue management channel is configured will depend on both the application and the prevailing traffic control philosophy. SmartSensor Advance has a large toolbox of channel, alert, and zone controls available to accommodate a wide variety of traffic control methodologies including the following:

- Off/on-ramp management
- Intersection management
- Queue length estimation
- Queue reduction
- Queue calling
- Vehicle counting to adapt signal timing
- Gap detection for safe and efficient queue reduction

In the sections below we will explore how to configure the SmartSensor Advance for each of these methods.

### Off-ramp Management

Spillback from an off-ramp onto a freeway presents serious dangers due to the high-speed differential between

the exit lanes and the main line. Because of this safety hazard, at critical times it is important to give priority to the off-ramp approach to the signalized intersection.

For this application, consider the length estimation method of queue management. If the queue is estimated to reach a specific point of interest (e.g. 400 ft./121.9 m from stop bar) then the intersection traffic controller can prioritize demand from the ramp when a rack card activates its contact closure channel.

## On-ramp Management

If mainline flow is near capacity, on-ramp queuing can be used to prevent the freeway from entering breakdown. However, in some locations, care must be made to make sure that the ramp queues do not spill back into the nearby intersections and cause arterial gridlock.

For this application, consider the queue length estimation method to address on-ramp metering problems. If the queue length extends beyond a point of interest, then the signal cycle frequency can be adjusted accordingly. If the queue becomes too long, consider turning off the meter and releasing the queue onto the freeway.

## Intersection Management

There are probably as many signal management methodologies as there are intersections. In some respects, that is a good thing because it allows operations to be customized for each intersection. However, it also makes us realize that a one-size-fits-all approach is not always the best policy. So while some intersections may best be controlled using queue length estimation, with others it is better to use vehicle counting to adapt signal timing. And in some cases, it may be beneficial to use a hybrid method. In the following sections we will explain how to program SmartSensor Advance for each control methodology.

For intersection management, the default Wavetronix recommendation is to use gap detection for safe and efficient queue reduction. This methodology can be used to manage intersection highway queues at isolated intersections, coordinated intersections, high-speed intersections, and at intersections where the standing queue extends beyond the 600-ft. (182.88 m) reach of SmartSensor Advance.

Queue reduction is a gap detection–based method of queue management that can be coupled with speed-based channel deactivation. When used in combination with dilemma zone protection, queue reduction provides superior management of high-speed signalized intersections. (See the knowledge base article Basic Traffic Signal Timing and Advance Detection for more information on dilemma zone issues and ETA-based gap detection.)

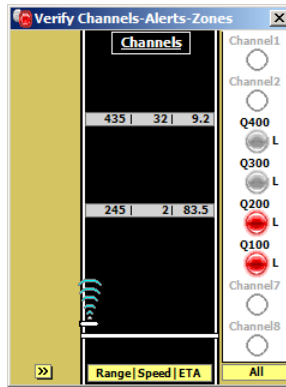
On coordinated arterials, using queue reduction on the mainline helps optimize split times on a cycle-by-cycle basis based on real-time demand. This is done by using a common controller feature sometimes referred to as “actuated coordinated” that allows the coordinated split to be extended by up to about ten seconds if warranted.

The conditions that warrant extension can be based on efficiency and safety. For example, an extension can be granted if a platoon is progressing slower than anticipated or if a platoon is longer than expected. On a high-speed arterial, platoons may also exhibit decision dilemma zone hazards which warrant green extension for a fraction of a second or more.

These possibilities underscore the advantage of using SmartSensor Advance on a coordinated mainline; demand on the cross-street and conflicting movements will be served more quickly if the mainline traffic flow does not warrant continued green extension.

## Basic Queue Length Estimation

The basic method of queue length estimation uses SmartSensor Advance’s ability to track moving vehicles as they stop and start in the queue. Length estimation is reported by activating as many as eight contact closure channels. When a contact closure channel is active, the queue has reached the associated point of interest on the roadway.

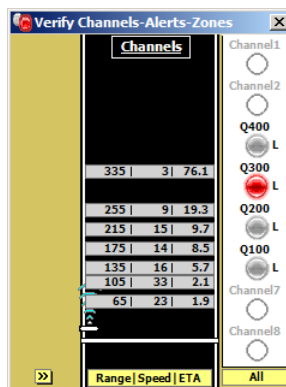


The above example reports queue activity at four setback distances from a stop bar: 100, 200, 300, and 400 ft. The channels labeled “Q100” and “Q200” are red to indicate that the channel is active because queue length is currently at least 200 ft. (61 m) from the stop bar. On the roadway view, a detection is shown at a range of 245 ft. from the stop bar with a speed of 2 mph; this indicates that the queue continues to grow beyond 200 ft. from the stop bar. No vehicles are shown in front of this vehicle because SmartSensor Advance is a passage detector, which means it tracks moving vehicles, but filters out stopped vehicles.

In order for the “Q100” through “Q400” channels to continuously activate a contact closure output, even when vehicles are stopped they are configured to latch and release based on vehicle tracking. They latch when a vehicle is tracked to a stopping point near the selected point of interest on the roadway. Similarly, the latched channels release when a vehicle is tracked through the selected area of the roadway at a relatively high speed.

To program a latched channel, two alerts are used: one is an ON alert, which specifies the conditions that cause the channel to activate; the other is an OFF alert, which specifies the conditions that cause the channel to deactivate. For basic queue estimation, the ON alert uses a low-speed activation threshold and the OFF alert uses a high-speed deactivation threshold.

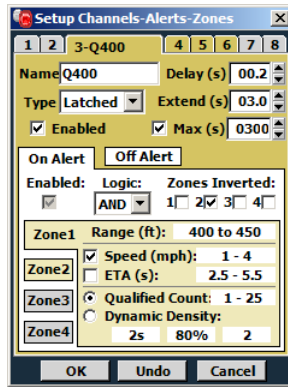
The figure below shows a screenshot of the queue at a point later in time than that in the figure above. The “Q300” contact closure channel still remains active because speeds in the vicinity have not yet surpassed the deactivation threshold. However, the “Q100” and “Q200” have deactivated because the vehicles at these ranges have begun to creep forward and the associated speeds are now above the selected thresholds.



## Enhanced Queue Length Estimation

In addition to activation and deactivation speed thresholds, SmartSensor Advance provides a suite of channel, alert, and zone controls to enhance queue length estimation (see SmartSensor Advance User Guide for more information):

- **Channel Extend Timer** – The extend timer can be used to smooth channel outputs by requiring that the channel stay on for a number of seconds each time it is activated. In the figure below, a three-second extension time is programmed.



- **Channel Delay Timer** – This timer can be used to require that specified ON-alert conditions persist for a selected duration of time before the channel activates. In the figure above, a 0.2 second delay is programmed. This setup time can be used to prevent premature activation due to momentary low-speed false detections.
- **Channel Max Timer** – This timer can deactivate a latched channel after a specified duration of time (assuming that the ON-alert conditions no longer exist) and can prevent the channel from sending a perpetual call in the event of a detection error.
- **ON alerts and OFF alerts**– These can be programmed to activate or deactivate based on criteria other than a single speed near a point on the roadway. For example, instead of activating a channel as soon as a speed less than 5 mph is detected between 400 and 450 ft., it may also be advantageous to specify that no fast vehicles are nearby. This additional logic can screen out false alerts when there is a mix of speeds on the roadway.

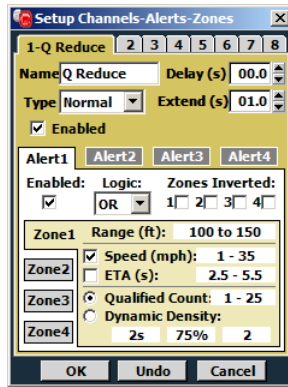
In order to add the requirement that there are also no fast cars nearby, the ON alert would be programmed with a second zone, AND logic and an inversion of zone 2 outputs. The second zone would be programmed to activate its output when nearby vehicles are traveling at relatively high speeds. The inversion of this output would then create the logical condition that vehicles in the vicinity must not be at high speeds. Finally, the AND logic would require that a slow speed vehicle must be detected at the same time that nearby high-speed vehicles are not detected.

## Queue Reduction

Queue reduction channels do not use queue length estimation. Instead, these channels monitor the range and speed of vehicles in a dissipating queue in order to detect gaps in traffic for efficient phase termination. On high-speed arterials, we recommend using queue reduction channels with advance detector channels to make sure detected gaps are both safe and efficient.

A queue reduction channel should be used with a minimum green time that will ensure vehicle movement at the location of the associated zone. The default location for a queue reduction channel is from 100 to 150 ft. (30.5 to 45.7 m) from the stop bar (see the figure below); a 15-second minimum green time is usually sufficient.

In some cases, you may also wish to use a queue reduction channel to hold green until a desired flow speed is reached. In the figure below, the Q Reduce channel will deactivate if a gap in traffic is detected or if the flow speeds are greater than 35 mph. This feature of queue reduction based queue management not only detects queues, but also provides additional control in managing their dissipation.



Speed-based deactivation is a critical tool when more than one detection channel is programmed to extend green. For example, when a queue reduction channels is used in combination with an advance detection channel, speed-deactivation of the queue reduction channel will ensure that the advance detection can terminate the phase as soon as the first safe gap in traffic is found.

## Queue Calling

If a phase or movement at a signalized intersection is on minimum recall, then detection is not necessary to call the phase. But if you would like to use SmartSensor Advance to call a phase, queue length estimation can be used.

For example, on minor side streets it may not be desirable to call a phase as soon as a single vehicle arrives at the stop line; it may be better to delay this call in order to minimize interruption of the mainline. However, if the queue on the minor side street quickly builds up to a considerable length, then you may want to call the side street with little or no delay.

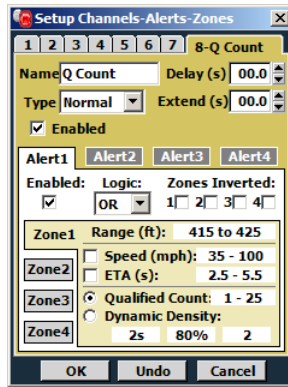
**Note.** *With queue calling channels, the delay should be programmed in the traffic controller (not using the SmartSensor Advance).*

## Queue Counting

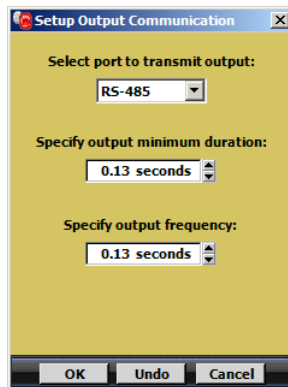
At some intersections it may be beneficial to count the volume of queuing traffic and modify signal timing accordingly. There are a couple of ways to do this:

- **Added Initial Method** – One simple way to modify timing is to increment the amount of initial green based on the number of vehicles arriving on red. The added initial method is an aspect of volume density control and works when the queue of traffic is contained within the 600-ft. (182.88-m) coverage area of the SmartSensor Advance. For more extensive queuing, additional methods must be used instead of, or in combination with, the added initial method.
- **Volume Counts Method** – A more comprehensive way to modify timing is to change to a different signal plan based on the volume of traffic. SmartSensor Advance volume counts are not produced by directly counting vehicles on a lane-by-lane basis as with SmartSensor HD, therefore SmartSensor Advance counts tend to be less accurate. Count errors can occur when vehicles in adjacent lanes merge, or when truck-trailer combinations are counted multiple times. However, these rough counts are accurate enough to be useful for making adjustments to signal timing.

In the figure below, the Q Count channel is configured by simply setting up a trip-line zone starting at 415 ft. from the sensor. When each tracked detection crosses through this area it will be signaled to the traffic controller as a contact closure. The traffic controller then counts these contact closures to detect incoming volume.



For proper counting via the traffic controller, SmartSensor Advance and the rack card must be configured appropriately.



The figure above shows the settings for communicating to a Click 172/174 rack card. The minimum duration of each contact closure is 130 ms and all standard traffic controllers should be capable of counting these pulses. When receiving data from SmartSensor Advance, the Click 172/174 racks cards should always be configured in Actuation mode.