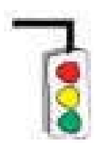
# Laboratory 4
# Impact of Detector and Timing Parameters on Arterial Street Operations at an Isolated Intersection



# CONTENTS (LABORATORY 4)

# 1. INTRODUCTION

## 1.1 Purpose

How is the operation of a high-speed approach on the main street different from that of a lower speed approach on the minor street? How does the speed of traffic on the intersection approach affect the detection design and the selection of the signal timing parameters? For higher speed approaches, when posted speeds exceed 35 miles per hour, many transportation agencies use advance detection. With advance detection, detectors are located some distance upstream of the stop bar, ensuring that vehicles will be given enough time to be able to safely clear the intersection.

In Laboratory 4, you will learn that the location of the detector must be considered together with other parameters such as the Minimum Green time and Vehicle Extension time. You will also learn how volume-density parameters can be used to improve the efficiency of the signal timing at a high-speed approach.

Specifically, we will address these issues:

- What is the effect of the Minimum Green time on the operation when advance detection is used?
- Can volume-density Variable Initial settings improve the operation of the intersection during the initial queue service period?
- What is the effect of a long Vehicle Extension setting time on the intersection operations after the initial queue is served? What is the effect of a short Vehicle Extension time setting?
- Can volume-density variable extension settings improve the operation of the intersection after the initial queue is served?

## 1.2 Goals and Learning Objectives

The goal of Laboratory 4 is to develop a detector design (location of detection zone) and timing design (Minimum Green time and Vehicle Extension time, as well as volume-density parameters) for the arterial street approach of an isolated intersection using advance detection.

When you have completed Laboratory 4 you will be able to:

- Analyze the performance of a high-speed approach when advance detection is used.
- Determine the optimal values of Minimum Green time and Vehicle Extension time required when advance detection is used.
- Identify issues associated with setting the Minimum Green time when advance detection is used and why it should be supplemented with either stop bar detection or the use of volume-density Variable Initial setting.
- Develop a timing plan that includes volume-density Variable Initial parameters to improve the operation during initial queue service time.
- Relate the duration of the Vehicle Extension time to the intersection operation after the initial queue is served.
- Develop a timing plan that includes volume-density variable extension (gap reduction) parameters to improve the operation after the initial queue is served.

## 1.3 Organization and Time Allocation

Laboratory 4 is divided into twelve sections, including this introduction. The eleven sections that follow and the approximate time allocated to each section are listed in Table 1.

Table 1 Laboratory sections and approximate completion times

| Section | Title | Approximate Time (min) |
|---|---|---|
| 1 | Introduction | 5 |
| 2 | Terms | 10 |
| 3 | High-speed approaches and advance detection | 10 |
| 4 | Experiment #1: Minimum Green setting for advance detection | 10 |
| 5 | Serving the initial queue when advance detection is used: two possible solutions | 10 |
| 6 | Experiment #2: Variable Initial setting for volume-density control | 20 |
| 7 | Experiment #3: Vehicle Extension setting for advance detection | 20 |
| 8 | Volume-density gap reduction process: how it works | 20 |
| 9 | Experiment #4: How gap reduction process works | 20 |
| 10 | Experiment #5: Gap reduction process for volume-density control | 20 |
| 11 | Experiment #6: Design exercise-setting volume-density parameters | 30 |
| 12 | Closure: summary of key points learned | 10 |

## 2. TERMS

Standard definitions for traffic signal terminology are provided by the National Electrical Manufacturers Association (NEMA) [9] and by the National Transportation Communications for ITS Protocol (NTCIP) 1202 document, "Object Definitions for Actuated Traffic Signal Controller Units" [2]. Definitions are also provided in the Federal Highway Administration's *Traffic Signal Timing Manual* [5]. The definitions presented here are adapted from these sources.

**Added Initial:** An interval that times concurrently with the Minimum Green interval, and is increased by each vehicle actuation received during the associated phase yellow and red intervals. The Added Initial is equal to the product of the number of vehicles arriving during the yellow and red intervals and the seconds per actuation.

**Gap in Effect:** The current value of the Vehicle Extension time after the gap reduction process has begun.

**Gap Reduction Process:** This process reduces the time before a phase will terminate from the Passage Time to the Minimum Gap. This process is determined by three controller timing parameters: Time Before Reduction (TBR), Time To Reduce (TTR) and Minimum Gap.

**Maximum Initial:** The maximum period of time for which the Added Initial can extend the initial green period.

**Minimum Gap:** The minimum gap is used during the gap reduction process and is the smallest value for a vehicle extension.

**Maximum Green:** The maximum length of time that a phase can be green in the presence of a conflicting call.

**Time Before Reduction (TBR)**: This period begins when the phase is green and there is a serviceable call on a conflicting phase. When this period is completed, the linear reduction of the Passage Time begins.

**Time To Reduce (TTR)**: The controller timing period that begins when the Time Before Reduction ends and controls the linear rate of reduction until the Minimum Gap is achieved.

**Variable Initial**: The Variable Initial is equal to the Added Initial, with the constraint that it must be greater than the Minimum Green or less than the Maximum Initial.

**Variable Initial Period:** This period is the length of the initial green time that is needed to serve the standing queue that is present between the advance detector and stop bar at the beginning of the green interval.

**Volume-Density Control**: This type of control includes two components, a variable initial period and a gap reduction process. The initial period is not fixed by the Minimum Green time, but rather it varies based on the number of vehicles in queue at the beginning of green. The gap reduction process provides a reduction in the Passage Time over time based on the duration of the extension period.

# 3. HIGH-SPEED APPROACHES AND ADVANCE DETECTION

How is the operation of the main street different from that of the minor street? One of the differences may be the speed of the traffic on the major street approach.

Many jurisdictions use what is known as advance detection, a detector located upstream a distance equal to the stopping distance for a vehicle traveling at the posted speed limit. One of the major concerns when this type of detection is used is to make sure that vehicles, after actuating the detector, are given enough time to safely clear the intersection. Vehicles further upstream will have ample distance to stop if the yellow and red clearance intervals are properly timed.

We define the concept of the “option zone” in which drivers may consider either stopping or attempting to clear the intersection when a yellow indication is displayed.

Figure 1 shows a typical option zone at a signalized intersection approach. As a group, drivers within a few seconds’ travel time from the intersection tend to be indecisive about their ability to stop at the onset of the yellow indication. This behavior yields a "zone of indecision" (option zone) in advance of the stop line, wherein some drivers may proceed and others may stop.

The option (indecision) zone location has been defined in several ways. Some researchers have defined it in terms of distance from the stop line. They define the beginning of the zone as the distance beyond which 90 percent of all drivers would stop if presented a yellow indication. They define the end of the zone as the distance within which only 10 percent of all drivers would stop. Another definition of the indecision zone boundary is based on observed travel time to the stop line. Chang, et al. [reference 4] found that 85 percent of drivers stop if they are more than 3 seconds from the stop line, regardless of their speed. Similarly, they found that drivers less than 2 seconds from the stop line almost always continue through the intersection.

A third definition of the beginning of the indecision zone is based on safe stopping sight distance (SSD). A method for computing this distance is described in Chapter 3 of the American Association of State Highway and Transportation Officials (AASHTO) document, *A Policy on the Geometric Design of Highways and Streets* [1].

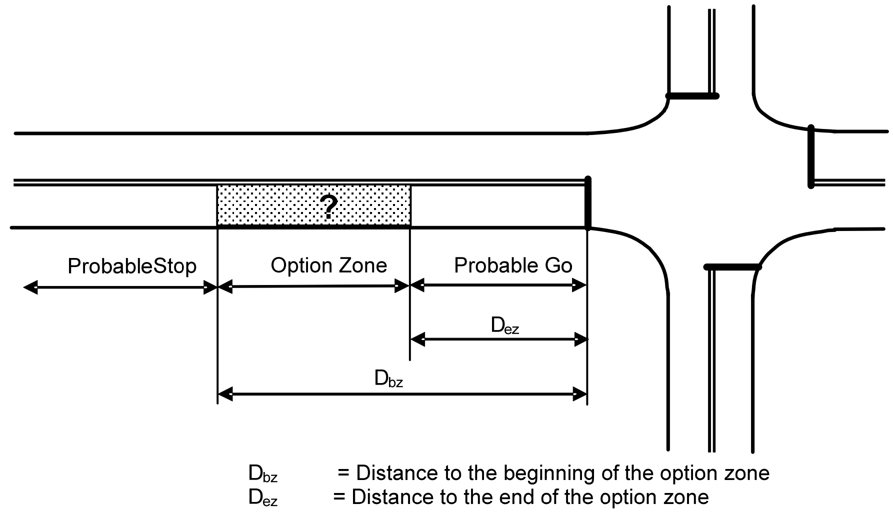



Figure 1 Option zone at signalized intersection [5]

The zone boundaries produced by these three definitions are compared in Figure 2. The boundaries based on distance typically have an exponential relationship. Those based on travel time have a linear relationship. Based on the trends shown in the figure, the beginning and end of the option (indecision) zone tend to be about 5.5 seconds and 2.5 seconds, respectively, travel time from the stop line. These times equate to about the ninetieth and tenth percentile drivers, respectively. It should be noted here that the option (indecision) zone exists on every intersection approach at the onset of every yellow indication, regardless of the yellow interval duration. It should not be confused with the dilemma faced by drivers when the change period (yellow plus red clearance) is too short relative to the time they need to perceive the yellow indication, determine whether there is distance to stop and, if not, to travel through the intersection before a conflicting movement receives a green indication.

## 3.1 Detector Placement

When advance detection is used, the detectors should be placed, at minimum, a distance equal to the stopping sight distance (SSD), the distance required for a vehicle traveling at the posted speed limit to stop safely at the intersection using a comfortable deceleration rate. The SSD equals vehicle speed multiplied by the reaction time plus the breaking distance. Table 2 lists the SSD for a range of vehicle speeds.

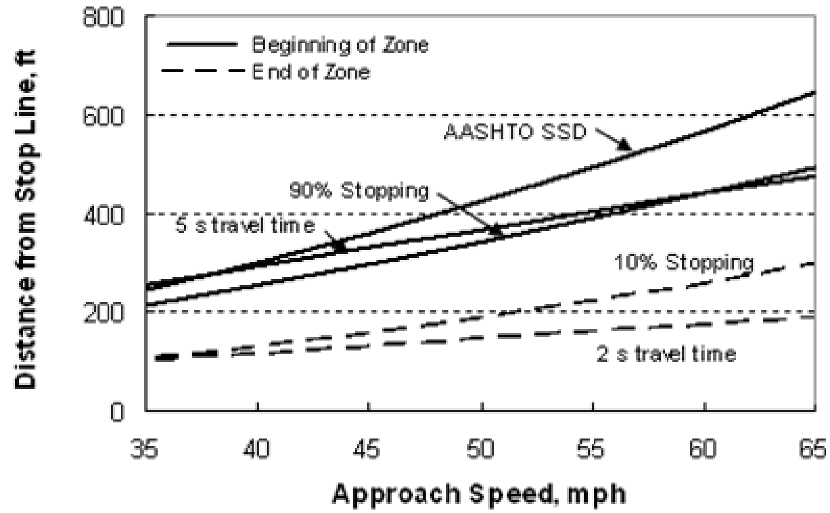



Figure 2 Distance to the beginning and end of the option zone [1]

Table 2 Stopping sight distance (SSD) for a range of design speeds

| Vehicle Speed (mph) | SSD (ft) |
|---|---|
| 20 | 73 |
| 25 | 104 |
| 30 | 141 |
| 35 | 184 |
| 40 | 232 |
| **45** | **285** |
| 50 | 344 |
| 55 | 408 |
| 60 | 477 |

In this laboratory, we will consider the EB approach at the State Highway 8 and Line Street intersection (see Figure 3). The approach has a speed limit of 45 miles per hour (see Figure 4). At this speed, a vehicle requires a minimum distance of 285 feet to stop (see Table 2). Accordingly, detectors are placed 285 feet upstream from the approach's stop bar, one in each of the approach lanes.


Figure 3 State Highway 8 and Line Street intersection

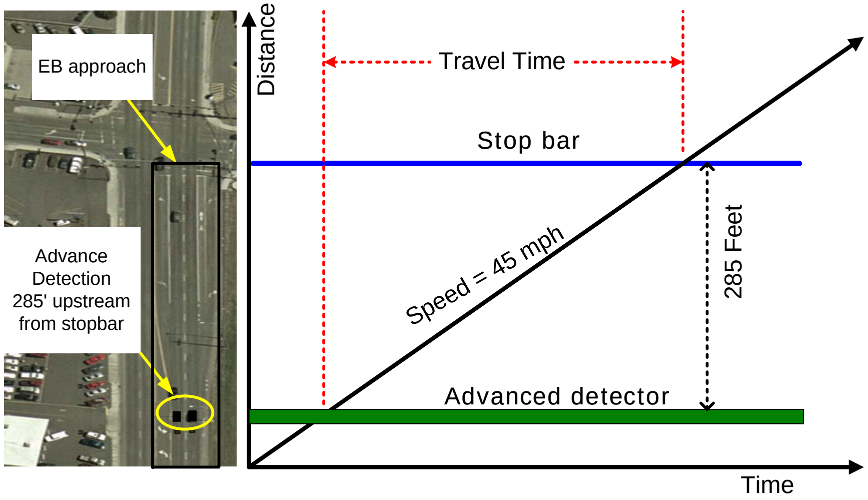



Figure 4 Vehicle trajectory along EB approach

## 3.2 Minimum Green Time

The Minimum Green time must be set consistent with driver expectancy, which will differ by approach (higher on the main street and lower on the cross street) and movement type (higher for through movements and lower for turns). Minimum Green time should be the time for vehicles to move into the intersection from the downstream end of the detection zone after adding a normal starting delay for the first vehicle in queue (normally from 3 to 4 seconds.)

In the absence of stop bar detection, the Minimum Green time for approaches with advance detection should be determined based on the time needed for the number of vehicles that can be stored between the detectors and the stop bar (maximum queue length downstream from the detector location) to be served. Figure 5 shows the Minimum Green time required to serve a range of queue lengths. This time is based on a start-up lost time of 3 seconds plus a saturation headway of 1.9 seconds for each vehicle in the queue and is based on a simulation study of headways in a departing queue [11].

For the EB approach of State Highway 8, with advanced detectors placed 285 feet upstream from the stop bar, the maximum possible queue length contained between the stop bar and detectors ranges from 12 to 14 vehicles, depending on the average vehicle length and average spacing between vehicles standing in the queue. This queue length range corresponds to a Minimum Green time that ranges from 26 seconds (for 12-vehicle per lane maximum queue) to 29.6 seconds (for 14-vehicle per lane maximum queue).

The Minimum Green time can be estimated using the following equation:

MG = tl + (h)(vehicles)

Where MG is the Minimum Green time (seconds), tl is the start-up lost time (seconds), and h is the saturation headway (seconds), and vehicles are the number of vehicles queued between stop bar and detection zone.

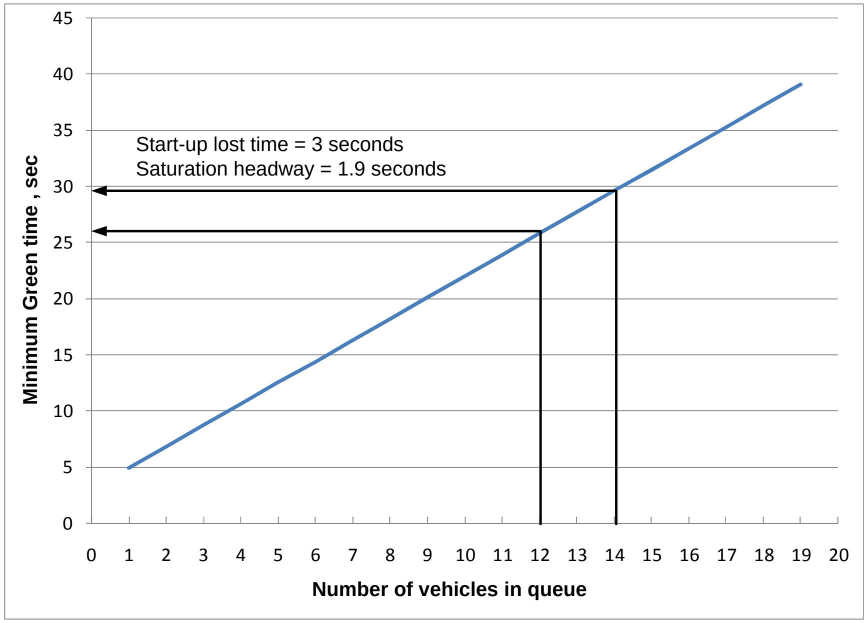



Figure 5 Minimum Green time required for various queue lengths

## 3.3 Minimum Vehicle Extension Time

As long as there is time left before the Maximum Green timer expires, a call received from this upstream detector will extend the phase an amount equal to the Vehicle Extension time. The Vehicle Extension time determines how “snappy” or “sluggish” signal operation will be. The minimum Vehicle Extension time should be based on the time needed by a driver to travel from the detection point to a point close enough to the stop bar that he/she will not choose to stop. Generally, a point 2 seconds from the stop bar will result in vehicles choosing not to stop, as a driver requires, on the average, 1 second after the onset of yellow to make a decision.

Figure 6 shows the EB approach of State Highway 8 with a speed of 45 mph. At this speed, a vehicle will travel approximately 65 feet each second. The travel time from the detector to the stop bar is 4.4 seconds. Here, (as shown in Figure 6) the minimum Vehicle Extension time is (4.4 – 2.0), or 2.4 seconds.

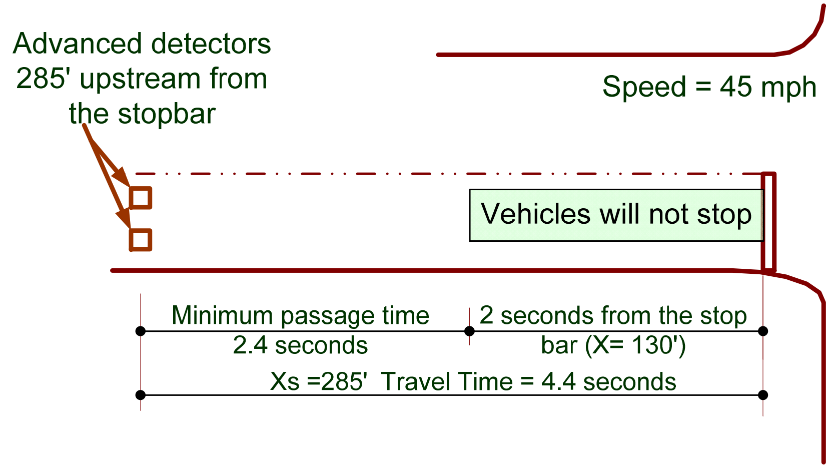



Figure 6 Option zone at EB State Highway 8

# 4. EXPERIMENT #1: MINIMUM GREEN SETTING FOR ADVANCE DETECTION

## 4.1 Learning Objective

- Be able to determine the Minimum Green time when advance detection is used.

## 4.2 Overview

In this experiment you will observe the EB approach of State Highway 8 (Figure 7). An advance detector is located at 285 feet upstream from the stop bar, a distance equal to the stopping sight distance for vehicles traveling at 45 miles per hour. The Minimum Green time is set at 25 seconds, the estimated time required for serving a queue of the 12 vehicles that can be stored between the advance detector and the stop bar. The focus of the experiment is to examine whether this Minimum Green time setting provides efficient operations during the queue service time.

## 4.3 Questions to Consider

As you begin this experiment, consider the following questions. You will come back to these questions once you have completed the experiment.

- In case 1 (12 vehicles/lane), is the Minimum Green time long enough to serve the last vehicle in the standing queue?
- In case 2 (7 vehicles/lane), is the Minimum Green time just long enough to serve the standing queue?
- What is the amount of unused green time (wasted green time) in each case?

## 4.4 List of Steps

You will follow these steps during this experiment:

- Start the MOST software tool and open the input file.
- View the signal controller information.
- Observe the simulation.

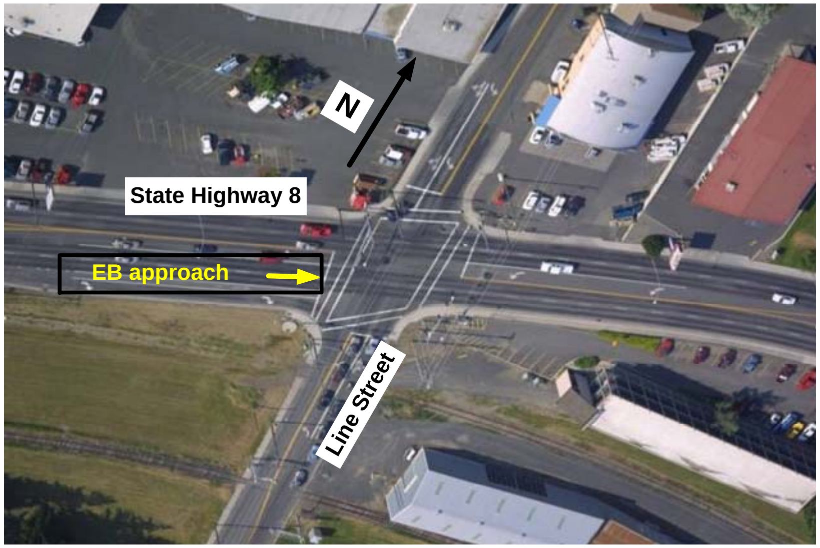



Figure 7 EB approach of State Highway 8 and Line Street intersection

## 4.5 Running the Experiment

You will consider two cases in this experiment:

- Case 1 has an initial queue of 12 vehicles per lane at the start of green (Figure 8).
- Case 2 has an initial queue of 7 vehicles per lane at the start of green (Figure 9).

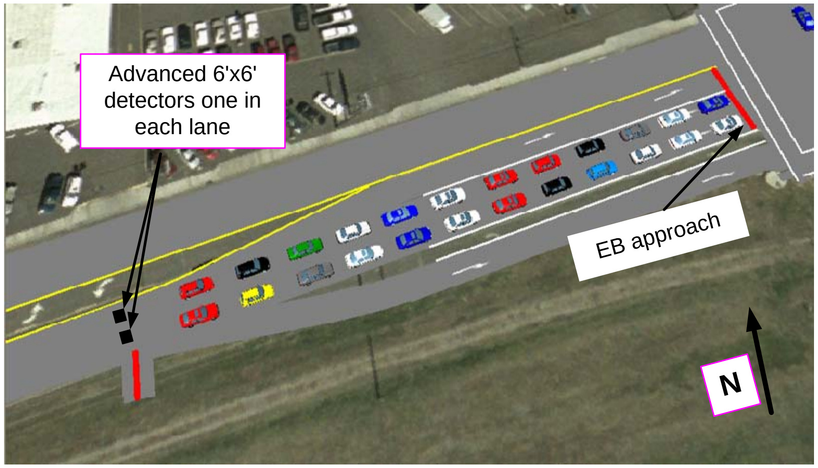



Figure 8 Case 1-Initial queue length of 12 vehicles/lane

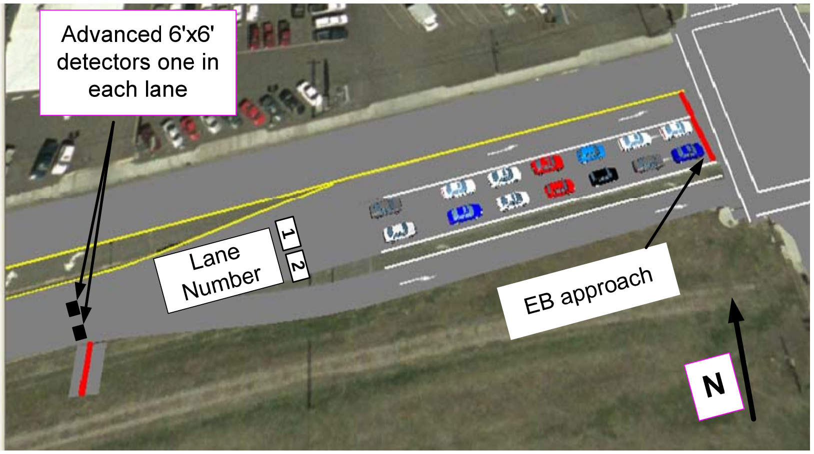



Figure 9 Case 2-Initial queue length of 7 vehicles/lane

### Step 1. Start the MOST software tool and open the input file.

- Start the MOST software tool and select “Open File.”
- Locate the “MOST input files” folder.
- Go to the “Lab4” folder, then the “Exp1” folder.
- Open the file: “lab4-exp1-1.inp.”
- Open the second input file: “lab4-exp1-2.inp.”

### Step 2. View the signal controller information.

- Signal controller information can be reviewed and modified using the ASC/3 virtual controller window and its front panel (shown in Figure 10).
- For this experiment, the Minimum Green is set to 26 seconds and the Maximum Green is set to 55 seconds. As our primary focus in this experiment is to serve the initial queue (the queue present at the start of green), the Vehicle Extension time is set to 0 seconds.

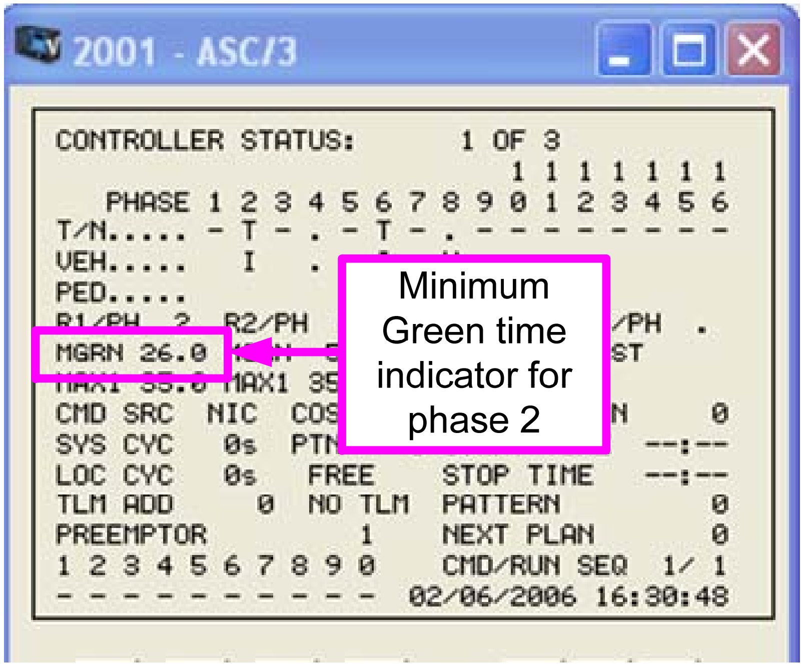



Figure 10 ASC/3 virtual controller window

**Step 3. Observe the simulation.**

- Select "Pause At" and enter "48.0".
- Start the simulation using the "Run Mode" button.
- Observe the animation of vehicles arriving at and departing from the EB approach of the intersection. You should also observe the controller status window (Figure 11).
- When the simulation is paused, use the "Run Mode Single Step" button to forward the simulation by 0.1 second. This will allow you to more easily observe and collect the required data.
- Record the simulation clock time for the events shown in Table 3 and Table 4. For each case, record the following data:
  - o Simulation time (clock time) for the start of green
  - o The time that the last vehicle in the queue passed the stop bar for each lane.
  - o The time that the green ended.
- Compute the duration of the unused green by subtracting the time that the last vehicle passed stop bar from the time that green ends.

Note: Lane 1 is the innermost lane and lane 2 is the outermost lane as indicated in Figure 9.

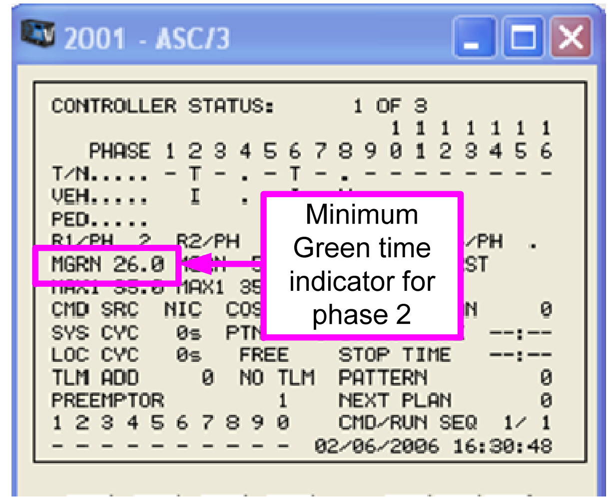



Figure 11 Controller status showing Minimum Green time

Table 3 Case 1 - Queue discharge characteristics

| Lane | Vehicles in queue (start of green) | Start of green (clock time, sec) | Time last vehicle passed stop bar (clock time, sec) | End of green (clock time, sec) | Unused green time (duration, sec) |
|---|---|---|---|---|---|
| *1* | *12* | | | | |
| *2* | *12* | | | | |

Table 4 Case 2 - Queue discharge characteristics

| Lane | Vehicles in queue (start of green) | Start of green (clock time, sec) | Time last vehicle passed stop bar (clock time, sec) | End of green (clock time, sec) | Unused green time (duration, sec) |
|---|---|---|---|---|---|
| *1* | *7* | | | | |
| *2* | *7* | | | | |

## 4.6 Discussion

Let's now consider each of the three questions that were presented at the beginning of this experiment.

- In case 1 (12 vehicles/lane), is the Minimum Green time long enough to serve the last vehicle in the standing queue?
- In case 2 (7 vehicles/lane), is the Minimum Green time just long enough to serve the standing queue?
- What is the amount of unused green time (wasted green time) in each case?

Take a few minutes to review each question and write brief answers to each question in the box on the right based on your observations from this experiment.

**Answers to questions:**

**1. In case 1 (12 vehicles/lane), is the Minimum Green time long enough to serve the last vehicle in the standing queue?**

→In case 1, an initial queue of 12 vehicles is present at the start of green in each lane. The queue stretches from the stop bar to just downstream of the advance detector. The Minimum Green time is set to 26 seconds, which is just enough time to serve the queue that is standing between the advance detector and stop bar. The green time ends approximately 4.6 seconds after the last vehicle in the queue leaves the intersection. These results are shown in Table 5.

**2. In case 2 (7 vehicles/lane), is the Minimum Green time just long enough to serve the standing queue?**

→In case 2, an initial queue of 7 vehicles is present at the start of green in each lane. The green time needed to serve this queue is approximately 13 seconds (the time the last vehicle needs to clear the intersection). After the queue dissipates, the green indication will be active until the Minimum Green timer reaches zero. The green time ends approximately 13.1 seconds after the last vehicle in the queue leaves the intersection. These results are shown in Table 6.

**3. What is the amount of unused green time (wasted green time) in each case?**

→In case 1, the amount of unused green time is 4.6 seconds. On the other hand, for case 2, there is an excessive amount of unused green time (13.1 seconds), which results in an inefficient operation.

It can be concluded from this experiment that having a long Minimum Green time will be efficient only when the queue length is equal to the distance between the detector and the stop bar.

There must be a different way to determine the Minimum Green time when using an advance detector. This will be discussed in the next section.

Table 5 Case 1 - Queue discharge characteristics

| Lane | Vehicles in queue (start of green) | Start of green (clock time, sec) | Time last vehicle passed stop bar (clock time, sec) | End of green (clock time, sec) | Unused green time (duration, sec) |
|---|---|---|---|---|---|
| *1* | *12* | *48.5* | *69.4* | *74.5* | *5.1* |
| *2* | *12* | *48.5* | *69.9* | *74.5* | *4.6* |

Table 6 Case 2 - Queue discharge characteristics

| Lane | Vehicles in queue (start of green) | Start of green (clock time, sec) | Time last vehicle passed stop bar (clock time, sec) | End of green (clock time, sec) | Unused green time (duration, sec) |
|---|---|---|---|---|---|
| *1* | *7* | *50.5* | *63.2* | *76.5* | *13.3* |
| *2* | *7* | *50.5* | *63.4* | *76.5* | *13.1* |

## 5. SERVING THE INITIAL QUEUE WHEN ADVANCE DETECTION IS USED: TWO POSSIBLE SOLUTIONS

We have seen that the advance detector effectively does its job of making sure that vehicles safely pass through the intersection or safely stop. However, there are some situations in which the advance detector alone is not sufficient since the Minimum Green time is based on the time needed to clear the queue length of 12 vehicles. Excessive unused green will result if the initial queue is shorter than this length.

There are two solutions to this problem. The first solution is to add a stop bar detector using presence detection, which would monitor vehicle gaps at the stop bar and terminate the phase when the queue has cleared. The advance detector extends the phase as needed when vehicles arrive on the approach.

This operation is illustrated in Figure 12 for an initial queue of 7 vehicles. The first two vehicles in the queue will be served during the 7 seconds of Minimum Green. After the Minimum Green expires, vehicles departing from the queue actuate the stop bar detectors. With each actuation, the green will be extended by 2 seconds (the value of the Vehicle Extension time), until the last vehicle in the queue leaves the intersection.

The second solution is to use volume-density control. Volume-density control consists of two separate components, a Variable Initial component that produces a minimum phase time that depends on the length of the queue that has formed during the yellow and red intervals, and a variable extension component that reduces the gap that will result in the phase gapping out, the longer the phase times. Together, both components produce an efficient operation using only the advance detector. Refer to section 2 for definitions of the volume-density parameters.

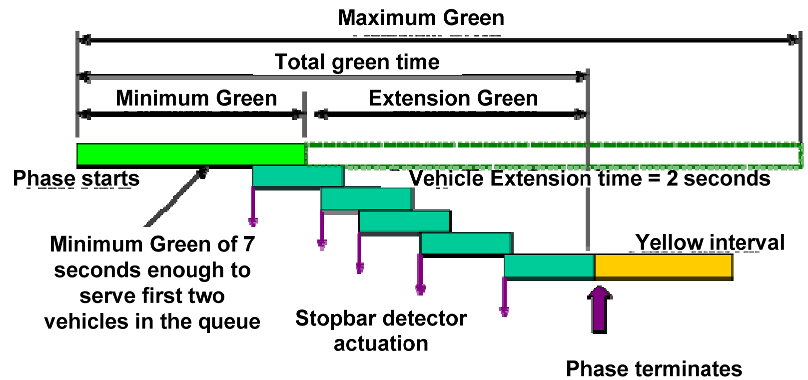



Figure 12 Green phase operation for advance and stop bar detection

## 5.1 Volume-Density Variable Initial: How It Works

The flexibility in the initial green period is provided through the following process. All vehicles passing by the advance detector during the yellow and red intervals are counted. The total number of vehicles that arrive during these two intervals are multiplied by the Seconds per Actuation parameter. This result produces the duration of time that is required to serve the initial queue.

The Variable Initial is equal to the product of the number of vehicles that arrive during yellow and red and the Seconds per Actuation parameter, with two constraints. It cannot be less than the Minimum Green time or greater than the Maximum Initial time.

In the example shown in Figure 13, seven vehicles arrive during the red and yellow intervals, forming an initial queue at the start of the green interval. The volume-density Variable Initial parameters are:

- Minimum Green = 7 seconds
- Seconds per Actuation = 2 seconds
- Maximum Initial = 33 seconds

The Added Initial is computed as:

- Added Initial = 7 vehicles x 2 seconds/actuation
- Added Initial = 14 seconds

As the Added Initial exceeds the value of the Minimum Green, the controller will implement a Variable Initial interval of 14 seconds.

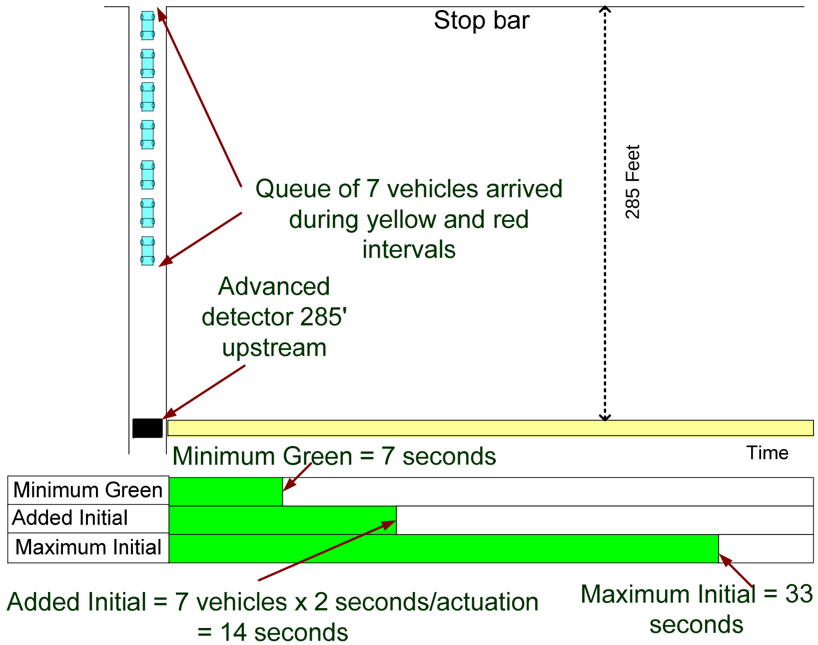



Figure 13 Volume-density Variable Initial timing parameters

## 5.2 Volume-Density Variable Initial: Timing Parameters

There are two steps required to calculate the volume-density timing parameters for the initial green period, determining the Maximum Initial time and determining the Seconds per Actuation.

The purpose of the Maximum Initial time is to serve the maximum queue that extends from the stop bar to the advance detector. Based on average values for headways as a function of position in queue, the chart on the right shows the Maximum Initial time as a function of the distance from the advance detector to the stop bar.

In our example, the advance detector is located 285 feet upstream of the stop bar. Depending on the vehicle composition in the queue, the length of the queue that extends from the stop bar to the advance detector ranges from 12 to 14 vehicles. Here, as shown in Figure 14, a Maximum Initial of 33 seconds should be used.


Figure 14 Maximum Initial values [10]

The Seconds per Actuation parameter determines the Added Initial time based on the number of vehicles that are detected by the advance detector during the previous yellow and red intervals. The Seconds per Actuation is computed as the ratio of the Maximum Initial and the maximum number of vehicles that could be stored between the advance detector and the stop bar.

$$Seconds\ per\ Actuation = \frac{Maximum\ Initial}{Number\ of\ vehicles}$$

Note: This equation considers passenger cars and trucks in the traffic stream.

The EB approach for State Highway 8 at Line Street consists of two lanes. The maximum number of vehicles that can be stored between the advance detector and the stop bar is 14 per lane, or 28 vehicles for both lanes. Using Figure 15, the Seconds per Actuation for two approach lanes, for approach detection is used, is:
(33 seconds) / (28 vehicles) = 1.2 seconds.

Similarly, for a one-lane approach, the Seconds per Actuation is:
(33 seconds) / (14 vehicles) = 2.4 seconds.

The value of the Seconds per Actuation parameter should be set to accommodate single and multiple lane detection. In Experiment #2, since multiple lane detection is used, the Seconds per Actuation was set to 1.0 seconds. This seems to provide an adequate Added Initial value and efficient operations (in case of passenger cars only in traffic stream). The optimal value for the Seconds per Actuation parameter should be determined based on field observations. Factors such as vehicle composition, queue discharge characteristics, and operating speed should be considered when making the decision regarding the optimal setting of the variable initial parameters.

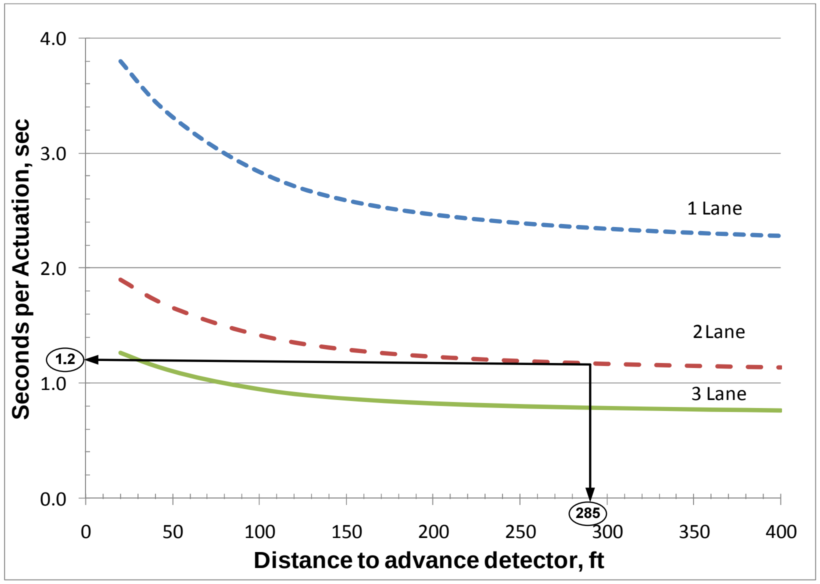



Figure 15 Seconds per Actuation as a function of distance to advance detector [10]

# 6. EXPERIMENT #2: VARIABLE INITIAL SETTING FOR VOLUME-DENSITY CONTROL

## 6.1 Learning Objective

- Be able to calculate the Variable Initial timing parameter necessary to serve the initial queue.

## 6.2 Overview

The Variable Initial timing parameters are determined at the beginning of each phase by the following algorithm:

- The Variable Initial time is equal to the product of the number of vehicles that arrived during yellow and red and the Seconds per Actuation parameter, with two constraints. It cannot be less than the Minimum Green time or greater than the Maximum Initial time.

Let's now consider three examples to see how the Variable Initial time varies with the number of actuations recorded during the previous yellow and red intervals. We will assume that the Minimum Green time is 7 seconds, there are two approach lanes, and the advance detector is placed 285 feet upstream from the stop bar.

Table 7 shows a set of example calculations for three different numbers of vehicles arriving during yellow and red. The Variable Initial ranges from 7 seconds (when one vehicle arrives during yellow and red) to 33 seconds (when 35 vehicles arrive during yellow and red). In the latter case, even though the product of the number of vehicles arriving during yellow and red and the Seconds per Actuation is 35, the Maximum Initial limits the Variable Initial to 33 seconds.

Table 7 Example calculations

| | **Example 1** | **Example 2** | **Example 3** |
|---|---|---|---|
| Vehicle arrivals during yellow and red | *1* | *17* | *35* |
| Maximum Initial (sec) | *33* | *33* | *33* |
| Minimum Green (sec) | *7* | *7* | *7* |
| Seconds per Actuation | *1* | *1* | *1* |
| Added Initial (sec) | *1* | *17* | *35* |
| Variable Initial (sec) | *7* | *17* | *33* |

[Note: Added Initial equals the Seconds per Actuation times the number of actuations.]

We should note that the definition of Added Initial used by the ASC/3 controller is different from the definition provided by NTCIP 1202 [2] or the *Traffic Signal Timing Manual* [5]. While this difference between the ASC/3 and the other two reference definitions should be noted, we will use the ASC/3 definition here. You are encouraged to remember both definitions.

For the ASC/3 controller, the Added Initial value is equal to the Variable Initial minus the Minimum Green time.

$$Added\ Initial = Varible\ Initial - Minumum\ Green\ time$$

In case 1, 24 vehicles (both lanes) are waiting at the stop bar at the beginning of the green interval.

$$Variable\ Initial\ =\ 24\ vehicles\ x\ 1.0\ seconds\ =\ 24\ seconds$$

Using the ASC/3 controller definition for the Added Initial, the result is:

$$Added\ Initial = 24 - 7 = 17\ seconds$$

You will observe in the ASC/3 control panel that the Minimum Green (7 seconds) will time down until it reaches zero, and then an Added Initial value of 17 seconds will start to time down until it reaches zero.

In case 2, 14 vehicles (both lanes) are waiting at the stop bar at the beginning of the green interval.

$$Variable\ Initial\ =\ 14\ vehicles\ x\ 1.0\ seconds\ =\ 14\ seconds$$

Using the ASC/3 controller definition, the Added Initial:

$$Added\ Initial = 14 - 7 = 7\ seconds$$

You will observe in the ASC/3 control panel that the Minimum Green (7 seconds) will time down until it reaches zero, and then an Added Initial value of 7 seconds will start to time down until it reaches zero. See Figure 16.

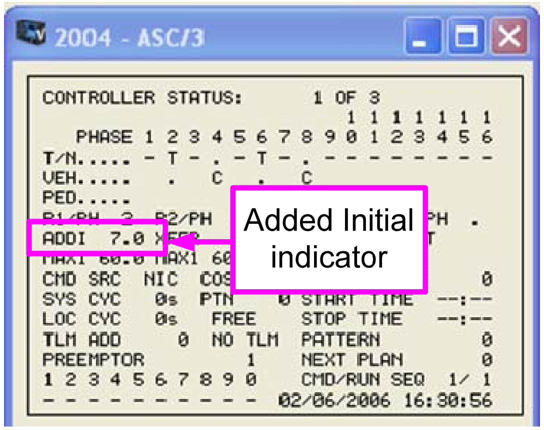



Figure 16 Added Initial indicator in the ASC/3 display panel

## 6.3 Question to Consider

As you begin this experiment, consider the following question. You will come back to this question once you have completed the experiment.

- Were the volume-density Variable Initial parameters effective in serving the initial queues at EB State Highway 8?

## 6.4 List of Steps

You will follow these steps during this experiment:

- Start the MOST software tool and open the input file.
- Verify that the signal timing settings in the ASC/3 controller have been correctly set for phase 2.
- Observe the simulation.

## 6.5 Running the Experiment

**Step 1. Start the MOST software tool and open the input file**

- Start the MOST software tool and select “Open File.”
- Locate the “MOST input files” folder.
- Go to the “Lab4” folder, then the “Exp2” folder.
- Open the file: “lab4-exp2-1.inp”.
- Open the second input file: “lab4-exp2-2.inp”.

**Step 2. Verify that the signal timing settings in the ASC/3 controller have been correctly set for phase 2.**

- Click on the “Open ASC3 Database Editor” button to activate the Controller Selection Dialog, as shown in Figure 17.
- Select controller 2003 to view in Database Editor, shown in Figure 18.
- Check the values for the Variable Initial timing parameters for phase 2, which should be set as follows:
    - o Minimum Green time = 7 seconds
    - o Seconds per Actuation = 1.0 seconds
    - o Maximum Initial = 33 seconds
- Close the dialog box and save the database file.

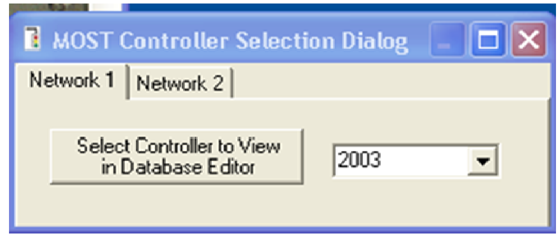



Figure 17 MOST controller selection

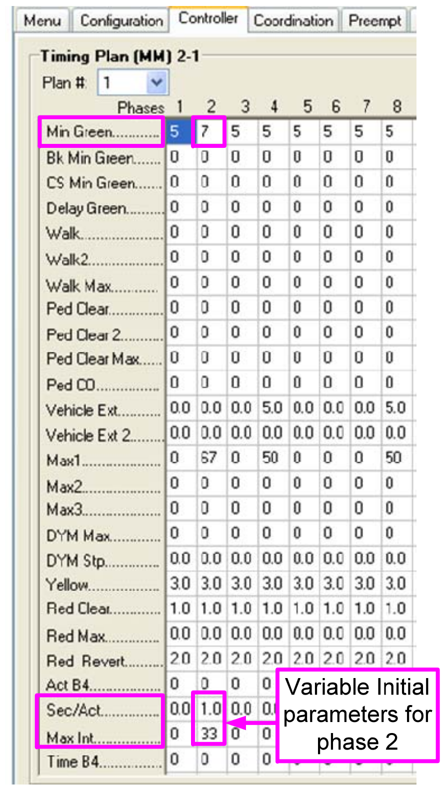



Figure 18 Variable Initial parameters in the Controller Database Editor

**Step 3.Observe the simulation.**

- Select "Pause At" and enter "48.0."
- Start the simulation using the "Run Mode" button.
- When simulation is paused, use the "Run Mode Single Step" button to forward the simulation by 0.1 second. This will allow you to more easily observe the simulation and collect the required data.
- Record the simulation time for the events shown in Table 8 and Table 9.
- For each lane, record the following data:
  - Simulation time (clock time) for the start of green.
  - The time that the last vehicle in the queue passed the stop bar.
  - The time that the green ended.
  - The duration of the unused green by subtracting the time that the last vehicle passed the stop bar from the time that green ends.

Table 8 Case 1 - Queue discharge characteristics

| Lane | Vehicles in queue (start of green) | Start of green (clock time, sec) | Time last vehicle passed stop bar (clock time, sec) | End of green (clock time, sec) | Unused green time (duration, sec) |
|---|---|---|---|---|---|
| *1* | *12* | | | | |
| *2* | *12* | | | | |

Table 9 Case 2 - Queue discharge characteristics

| Lane | Vehicles in queue (start of green) | Start of green (clock time, sec) | Time last vehicle passed stop bar (clock time, sec) | End of green (clock time, sec) | Unused green time (duration, sec) |
|---|---|---|---|---|---|
| *1* | *7* | | | | |
| *2* | *7* | | | | |

## 6.6 Discussion

Let's now consider the question that was presented at the beginning of this experiment.

- Were the volume-density Variable Initial parameters effective in serving the initial queues at EB State Highway 8?

Take a few minutes to review each question and write brief answers to each question in the box on the right based on your observations from this experiment.

| Answer to question: |
|---|
| |

**1. Were the volume-density Variable Initial parameters effective in serving the initial queues at EB State Highway 8?**

→As can be seen from the summary of the results, presented in Table 10 and Table 11, the amount of unused green time for both cases with varying queue length is 3 seconds in case 1, and 1 second in case 2. This indicates that the volume-density Variable Initial setting, when used with advance detection, can effectively serve the initial queue with a minimal amount of unused green, which results in an efficient operation.

Table 10 Queue discharge characteristics for case 1

| Lane | Vehicles in queue (start of green) | Start of green (clock time, sec) | Time last vehicle passed stop bar (clock time, sec) | End of green (clock time, sec) | Unused green time (duration, sec) |
|---|---|---|---|---|---|
| 1 | 12 | 49.7 | 70.8 | 73.7 | 2.9 |
| 2 | 12 | 49.7 | 71.2 | 73.7 | 2.5 |

Added Initial (in ASC/3 control panel) for case 1=
24 vehicles x (1.0 second) – 7 seconds (min green) = 17 sec

Table 11 Queue discharge characteristics for case 2

| Lane | Vehicles in queue (start of green) | Start of green (clock time, sec) | Time last vehicle passed stop bar (clock time, sec) | End of green (clock time, sec) | Unused green time (duration, sec) |
|---|---|---|---|---|---|
| 1 | 7 | 49.7 | 62.6 | 63.7 | 1.1 |
| 2 | 7 | 49.7 | 62.5 | 63.7 | 1.2 |

Added Initial (in ASC/3 control panel) for case 2 =
14 vehicles x (1.0 second) – 7 seconds (min green) = 7 sec

# 7. EXPERIMENT #3: VEHICLE EXTENSION SETTING FOR ADVANCE DETECTION

## 7.1 Learning Objective

- Be able to understand how the Vehicle Extension setting affects the operation of the intersection after the initial queue is served when advance detection is used.

## 7.2 Overview

In this experiment, you will examine the operation of the high-speed approach after the initial queue is served. Once the Variable Initial period has expired, and the initial queue has been served, the phase may continue to extend if the following two conditions are met:

- The Vehicle Extension timer has not expired.
- The Maximum Green time has not been reached.

While the queue is dissipating, vehicles arrive and join the queue or are slowed down by the queue. The volume-density Variable Initial period is designed to serve only the vehicles in the standing queue. But the green time should be extended to also serve those vehicles slowed down by and eventually joining the queue.

The extension of the green depends on the Vehicle Extension setting. It could be argued that it needs to be set large enough to serve slower moving vehicles slowed down by and joining the queue as the queue dissipates. However, a Vehicle Extension time of this duration may cause inefficiency in phase operations once all vehicles are moving at free flow speed.

In this experiment, you will observe the effects of the Vehicle Extension time on the operation of the EB approach. You will consider two different settings of Vehicle Extension time: 3 seconds and 5 seconds.

From your observations of the two simulations, you will be able to identify the effect of the Vehicle Extension time setting on intersection operations when advance detection is used and to relate the Vehicle Extension setting to the quality of intersection operations after the initial queue is served.

## 7.3 Questions to Consider

As you begin this experiment, consider the following questions. You will come back to these questions once you have completed the experiment.

- Does a 3 second Vehicle Extension time provide a safe and efficient operation for the approach?
- Does a 5 second Vehicle Extension time provide a safe and efficient operation for the approach?

## 7.4 List of Steps

You will follow these steps during this experiment:

- Open the movie file.
- Observe the simulation.

## 7.5 Running the Experiment

### Step 1. Open the movie file.

- Locate the “MOST input files” folder.
- Go to the “Lab4” folder, then the “Exp3” folder.
- Open the file: “lab4-exp3.wmv.”
- Pause the movie file until you have read the instructions in step 2.

### Step 2. Observe the simulation.

- Our focus in this experiment will be on vehicles arriving after the signal indication turns green that join the initial queue and vehicles arriving at free flow speed after the queue has been served. Observe the trajectories of these vehicles as they arrive and pass through the intersection.
- Watch and observe (Figure 19) two cycles for case 1 (on the left) and one cycle for case 2 (on the right). Make notes regarding your observations in the box at right.
- In case 1,
  - o Observe the vehicles that are slowed down by the queue after the green starts and whether all of these vehicles are served or not.
  - o Observe how the green interval terminates, either gapping out or maxing out.
- In case 2,
  - o Observe vehicles arriving at free flow speed that are still served.
  - o Observe the duration of green time.
- Restart the movie file.

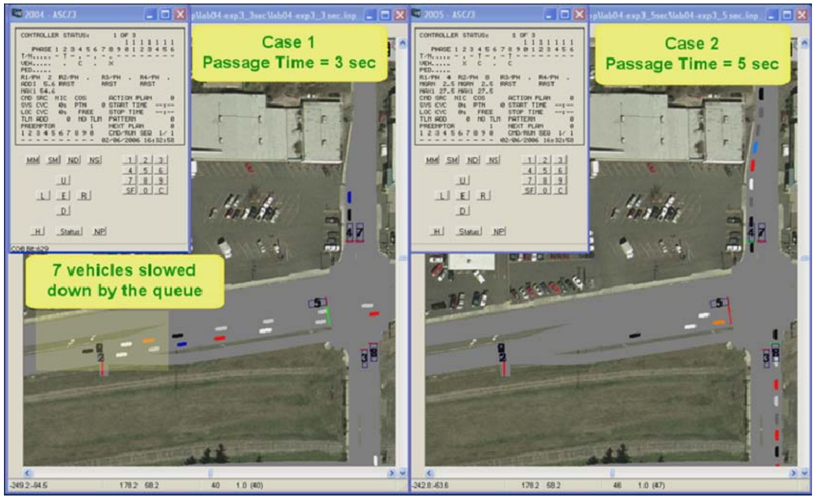



Figure 19 Case 1 and case 2

**Observations:**

## 7.6 Discussion

Let's now consider each of the two questions that were presented at the beginning of this experiment.

- Does a 3 second Vehicle Extension time provide a safe and efficient operation for the approach?
- Does a 5 second Vehicle Extension time provide a safe and efficient operation for the approach?

Take a few minutes to review each question and write brief answers to each question in the box on the right based on your observations from this experiment.

**Answers to questions:**

As discussed in Section 3, any vehicle passing the detection zone on green needs at least 4.4 seconds to travel the distance (285 feet) between the detector and the intersection. This value was obtained assuming that the vehicle is traveling through the intersection approach with a speed equal to the speed limit (45 mph). A minimum Vehicle Extension time of 2.4 seconds gives the vehicle enough time to be at a distance of 2 seconds from the stop bar. This allows the vehicle to clear the intersection during the yellow interval.

You have observed a total of 112.5 seconds of simulation time. This duration includes two cycles for case 1 and one cycle for case 2. One cycle only for case 1 is discussed here.

**1. Does a 3 second Vehicle Extension time provide a safe and efficient operation for the approach?**

→The results shown in Table 12 are for one cycle for case 1. The green interval starts at t = 165.8 seconds and gaps out at t = 183.3 seconds, with 17.5 seconds for the green interval. Vehicles 19 through 25 enter the detection zone while the green indication is on. Vehicles 19 and 20 were able to pass through the intersection during green. Vehicles 21 and 22 were able to pass during the yellow interval while vehicles 23, 24, and 25 stopped for the red light.

It is clear that a 3 second value of Vehicle Extension time, while appropriate for vehicles traveling at the speed limit, is not appropriate to serve vehicles delayed at the intersection due to the initial queue. A longer Vehicle Extension time should be used to serve the vehicles arriving during the early stages of the green interval slowed by the dissipating queue.

Table 12 Time events for Experiment #3 - case 1 (first cycle)

| Vehicle Number | Time vehicle enters detection zone (sec) | Minimum Green timer (sec) | Added initial timer (sec) | Time vehicle exits stop bar (sec) | Travel time (sec) |
|---|---|---|---|---|---|
| *19* | *169.5* | *3.2* | | *183.6* | *13.4* |
| *20* | *170.3* | *2.4* | | *184.0* | *13.2* |
| *21* | *172.1* | *0.6* | | *185.4* | *12.3* |
| *22* | *172.6* | *0.1* | | *186.3* | *13.1* |
| *23* | *174.4* | | *9.3* | x | - |
| *24* | *176.2* | | *7.5* | x | - |
| *25* | *178.6* | | *5.1* | x | - |

X = vehicles stopped for red light

**2. Does a 5 second Vehicle Extension time provide a safe and efficient operation for the approach?**

→You observed one cycle for case 2. The green interval starts at t = 209.8 seconds and the phase maxes out at t = 276.8 seconds, resulting in a green interval duration of 67 seconds. A total of 53 vehicles pass through during this green interval of 67 seconds. Vehicles number 1 through number 25 pass the intersection during the Variable Initial period. Vehicles 26 through 53 enter the detection zone during green, and all pass through the intersection during the extension period of green except for vehicle number 53, which passes during yellow.

Headways and unoccupancy times for vehicles 25 through 53 at the advance detector are shown in Figure 20.
Figure 21 shows an enlarged view for the simulation time from 220 to 240 seconds. For vehicles 26, 27, 28, and 29, the headways are 1.4, 2.9, 2.2, and 4.5 seconds. The unoccupancy times for the same vehicles are 0.9, 2.6, 1.8, and 4.1 seconds respectively. It should be our goal to terminate the phase when the headway exceeds the maximum allowable headway.

In this case, a Vehicle Extension time of 5 seconds was long enough to allow all vehicles to clear the intersection. However, once the initial queue, and the vehicles that joined the queue after the start of green, cleared the intersection, and vehicles reached their free flow speed (45 mph), the longer Vehicle Extension time resulted in inefficient operations as the phase was extended to the Maximum Green.

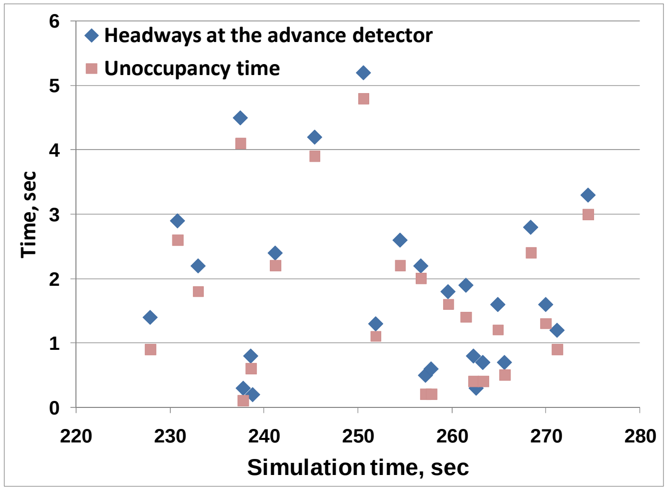



Figure 20 Headways and unoccupancy times

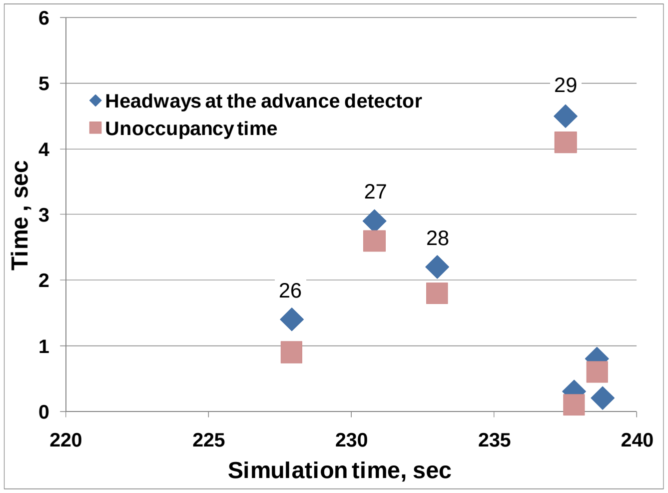



Figure 21 Headways and unoccupancy times

It can be argued that it is better to accommodate vehicles that are a part of the standing queue as well as vehicles delayed by the departing queue by one value of Vehicle Extension time. A second, and lower, value of Vehicle Extension time would be used after the queue has cleared. This outcome can be achieved by using the volume-density gap reduction setting, to be discussed in the next section.

# 8. VOLUME-DENSITY GAP REDUCTION PROCESS: HOW IT WORKS

## 8.1 Gap Reduction Process

As seen in the previous section, once the Variable Initial period has expired, the phase may continue to time as long as the Vehicle Extension timer has not expired or the Maximum Green time has not been reached.

As we saw in Experiment#3, the Vehicle Extension time should be set to provide for adequate time to ensure that slower moving vehicles, especially those forced to slow down for vehicles in the standing queue, have enough time to clear the intersection. However, once all vehicles are moving at free flow speed, this relatively large Vehicle Extension time could lead to excessive green time and inefficient phase operation.

To address this problem, the allowable time between vehicle calls is reduced as the phase time progresses, using the volume-density gap reduction process. The gap reduction process includes two timing parameters, the Time Before Reduction and the Time to Reduce. The Time Before Reduction timer begins once a serviceable conflicting call has been placed. While the Time Before Reduction process times down, the Vehicle Extension time is a constant value. Once the Time Before Reduction timer expires, the Time to Reduce timer begins. Once this timer starts, the Vehicle Extension reduces by a linear reduction process. When the Time to Reduce reaches zero, the Vehicle Extension is set to the Minimum Gap, as illustrated in Figure 22.

It should be noted that some controllers execute the Gap Reduction per Actuation in a step function rather than a linear reduction. The gap reduction process continues and the phase will be extended if the gap between vehicles at the detector location is less than the Minimum Gap.

See Figure 24 for recommended values from the *Traffic Signal Timing Manual* [5].

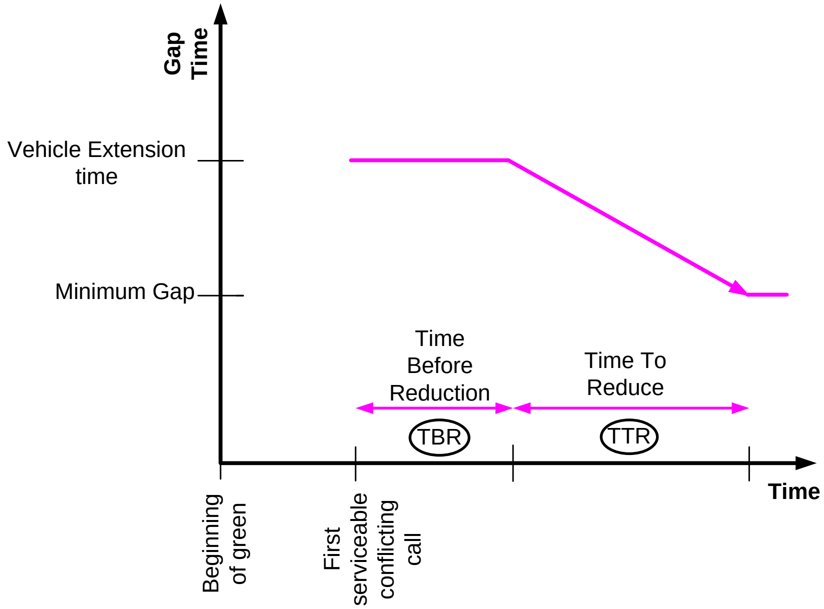



Figure 22 Gap Reduction process

## 8.2. Gap Reduction Parameters (Variable Extension)

Following is an example calculation to illustrate the gap reduction process. Suppose the following timing parameters have been set:

- Vehicle Extension time = 5 seconds
- Minimum Gap = 2.5 seconds
- Time Before Reduction = 10 seconds
- Time To Reduce = 30 seconds

Further, assume that the first serviceable conflicting call is received 20 seconds after the beginning of green. See Figure 23.

When does the gap reduction process begin and end?

The first serviceable conflicting call is received at 20 seconds after the beginning of green. At this point, the Time Before Reduction timer begins and runs for 10 seconds. It expires at 30 seconds after the beginning of green. At this point, the gap reduction process begins. The Vehicle Extension time starts at 5.0 seconds, and is reduced in a linear manner until it reaches the Minimum Gap value of 2.5 seconds. This occurs 30 seconds after the Time to Reduce process begins.

What is the real effect or purpose of the gap reduction process? During the queue clearance process, we are often conservative in accepting gaps that may be somewhat longer than the saturation headway in order to keep the phase timing to serve the entire queue. Once the queue has cleared, we can become more aggressive about accepting shorter and shorter gaps before terminating the phase, ensuring a more efficient phase operation. This is the essence of the gap reduction process.

Figure 24 shows the Gap reduction parameters recommended by the Federal Highway Administration, *Traffic Signal Timing Manual* [5].

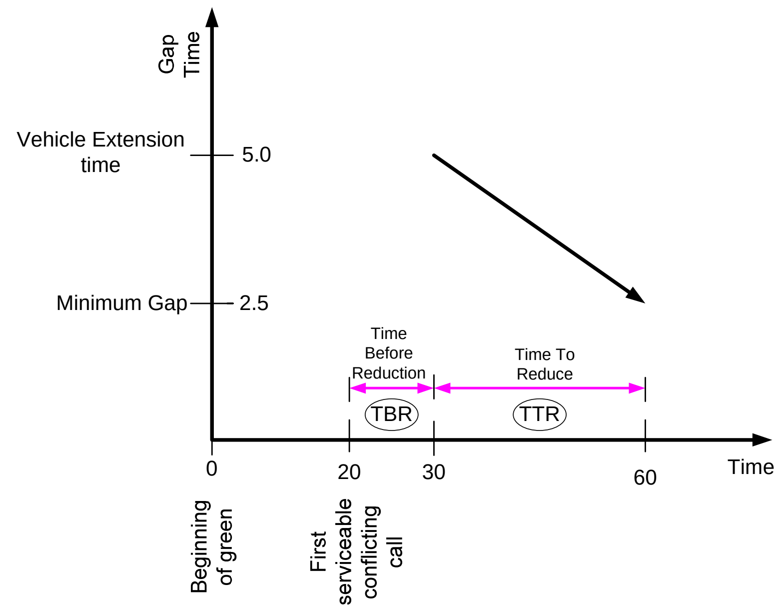



Figure 23 Gap Reduction parameters example

| Minimum Green Interval, s | Time Before Reduction [1], s | Maximum Green, s | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
| | | Time To Reduce, s | | | | | | | | | | |
| 5 | 10 | 8 | 10 | 13 | 15 | 18 | 20 | 23 | 25 | 28 | 30 | 33 |
| 10 | 10 | 5 | 8 | 10 | 13 | 15 | 18 | 20 | 23 | 25 | 28 | 30 |
| 15 | 15 | N/A | 5 | 8 | 10 | 13 | 15 | 18 | 20 | 23 | 25 | 28 |
| 20 | 20 | N/A | N/A | 5 | 8 | 10 | 13 | 15 | 18 | 20 | 23 | 25 |

Notes:
1 - Time before reduction should always be 10 s or more in length.
N/A - Gap reduction is not applicable to this combination of minimum and maximum green settings.

Figure 24 Gap Reduction parameters values, [5]

# 9. EXPERIMENT #4: HOW GAP REDUCTION PROCESS WORKS

## 9.1 Learning Objective

- Understand how the gap reduction process works.

## 9.2 Overview

In this experiment, you will observe how the volume-density gap reduction settings (the Time Before Reduction and the Gap in Effect) work in the ASC/3 traffic controller.
Gap in Effect is the term used in the ASC/3 controller for the Vehicle Extension time while volume-density operation is in effect. Gap in Effect is defined as the reduced Vehicle Extension time in effect at a given point.

## 9.3 Question to Consider

- How does the gap reduction process work?

## 9.4 List of Steps

You will follow these steps during this experiment:

- Start the MOST software tool and open the input file.
- View controller parameters.
- Observe the simulation.

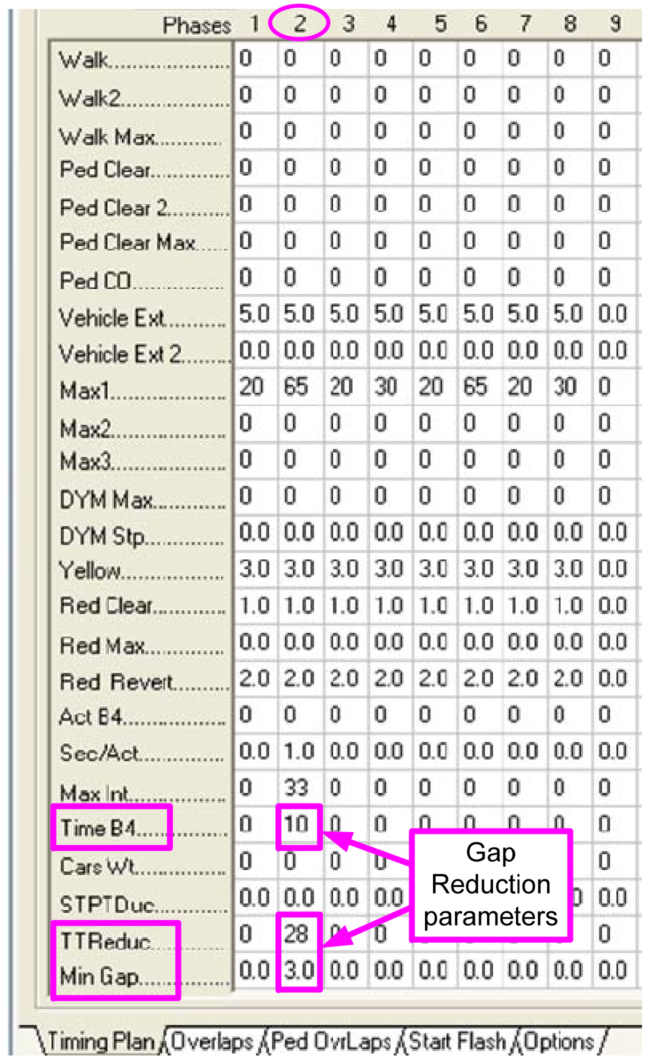
## 9.5 Running the Experiment

**Step 1. Start the MOST software tool and open the input file.**

- Start the MOST software tool and select "Open File."
- Locate the "MOST input files" folder.
- Go to the "Lab4" folder, then the "Exp4" folder.
- Open the file: "lab4-exp4.inp."

**Step 2. View controller parameters.**

- Select "Open ASC3 Database Editor."
- Select controller 2005 to view in Database Editor.
- Check controller settings for phase 2 to make sure that the following settings have been made (Figure 25):
    - o Minimum Green time = 7 seconds
    - o Maximum Initial = 33 seconds
    - o Seconds per Actuation = 1.0 seconds
    - o Time Before Reduction = 10 seconds
    - o Vehicle Extension time = 5.0 seconds
    - o Minimum Gap = 3.0 seconds
    - o Time To Reduce = 28 seconds
    - o Maximum Green = 65 seconds
- Close the dialog box and save the database file



| Phases | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Walk | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Walk2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Walk Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped CO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vehicle Ext | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 0.0 |
| Vehicle Ext 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Max1 | 20 | 65 | 20 | 30 | 20 | 65 | 20 | 30 | 0 |
| Max2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Max3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DYM Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DYM Stp | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Yellow | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 0.0 |
| Red Clear | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 |
| Red Max | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Red Revert | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 0.0 |
| Act B4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sec/Act | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Max Int | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Time B4 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cars Wt | 0 | 0 | 0 | 0 | [illegible] | [illegible] | [illegible] | [illegible] | 0 |
| STPTDuc | 0.0 | 0.0 | 0.0 | 0.0 | [illegible] | [illegible] | [illegible] | [illegible] | 0.0 |
| TTReduc | 0 | 28 | 0 | 0 | [illegible] | [illegible] | [illegible] | [illegible] | 0 |
| Min Gap | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |



Figure 25 Database editor for Experiment#4

### Step 3. Observe the simulation

- Select “Pause At” and enter “58.0”.
- Start the simulation using the “Run Mode” button.
- Click once on “Status” on the ASC/3 control panel, then click twice on “NP” (for Next Page) as shown in Figure 26. The volume-density timing window will be displayed (see Figure 27).
- When the simulation is paused, press the “Run Mode Single Step” button to forward the simulation by 0.1 second to t = 58.4.
- At t = 58.4 seconds, a conflicting call appears on the SB approach. At the same time, on the ASC/3 controller display, you will see:
  - o Time Before Reduction = 10 seconds
  - o Gap in Effect = 5 seconds
- While you are forwarding the simulation by single steps, note that the Time Before Reduction process times down until it reaches zero. While the Time Before Reduction process is timing down, the Gap in Effect value equals 5 seconds, the Vehicle Extension time.
- When the Time Before Reduction reaches zero, you will notice a linear reduction in the Gap in Effect value. This process will reduce the Vehicle Extension time from 5 seconds to the Minimum Gap value of 3 seconds. Once Gap in Effect reaches the Minimum Gap, it will extend the green interval by 3 seconds for each vehicle actuation until the phase gaps out or maxes out. The time it takes for the Vehicle Extension time to be reduced from 5 seconds to 3 seconds is equal to the Time to Reduce, in this case 28 seconds.

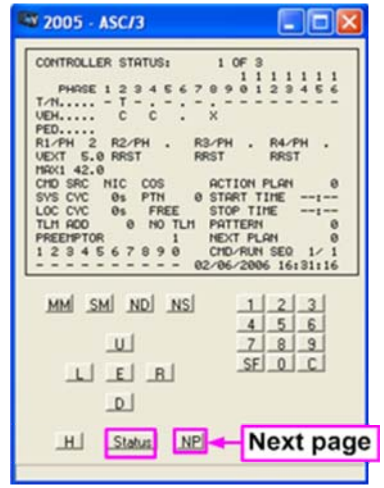



Figure 26 ASC/3 controller status window

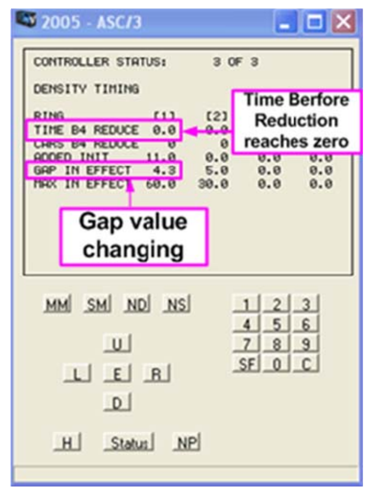



Figure 27 Time Before Reduction and Gap in Effect, ASC/3 controller status window

## 9.6 Discussion

Let's now consider the question that was presented at the beginning of this experiment.

- How does the gap reduction process work?

Take a few minutes to review the question and write a brief answer in the box on the right based on your observations from this experiment.

**Answer to question**:

## 1. How does the gap reduction process work?

→The Time Before Reduction and the Gap in Effect values that you observed in the ASC/3 display are shown in Figure 28 and Table 13.

Figure 28 shows the Time Before Reduction period from the reception of the conflicting call at t = 58.4 to the end of this period 10 seconds later. It then shows the Time to Reduce period as the Gap in Effect is reduced from 5 seconds to 3 seconds. Each vehicle call is indicated by a diamond shape in the figure.

Table 13 shows the time each vehicle enters the detection zone and the value of the Gap in Effect at that point. The phase gaps out at t = 103.8, when the unoccupancy time exceeds the Gap in Effect time.

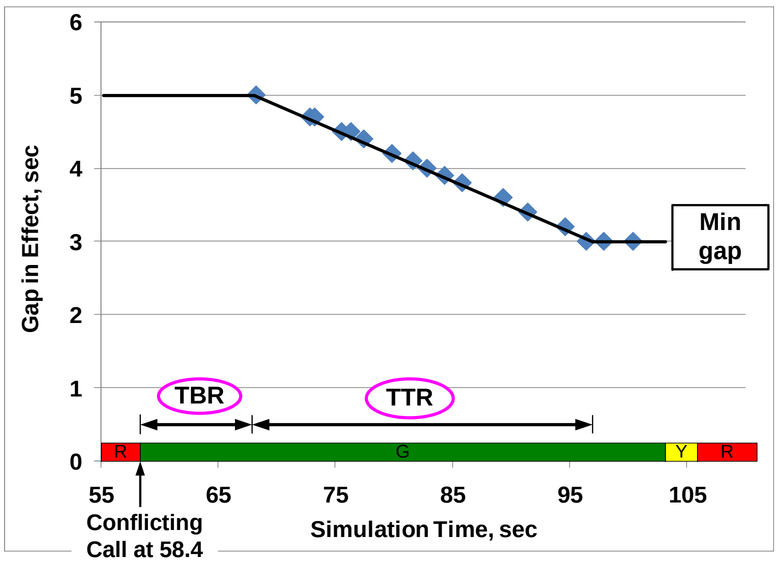



Figure 28 Gap Reduction process for Experiment #4

Table 13 Time events for Experiment #4

| Vehicle number | Time vehicle enters (seconds) | Gap in effect (seconds) |
|---|---|---|
| 24 | 68.2 | 5.0 |
| 25 | 72.8 | 4.7 |
| 26 | 73.2 | 4.7 |
| 27 | 75.5 | 4.5 |
| 28 | 76.3 | 4.5 |
| 29 | 77.4 | 4.4 |
| 30 | 79.8 | 4.2 |
| 31 | 79.8 | 4.2 |
| 32 | 81.6 | 4.1 |
| 33 | 82.8 | 4.0 |
| 34 | 84.3 | 3.9 |
| 35 | 85.8 | 3.8 |
| 36 | 89.3 | 3.6 |
| 37 | 91.4 | 3.4 |
| 38 | 94.6 | 3.2 |
| 39 | 96.4 | 3.0 |
| 40 | 97.9 | 3.0 |
| 41 | 100.4 | 3.0 |

# 10. EXPERIMENT #5: GAP REDUCTION PROCESS FOR VOLUME-DENSITY CONTROL

## 10.1 Learning Objective

- Be able to apply volume-density gap reduction settings to effectively manage the operations after the initial queue is served.

## 10.2 Overview

In this experiment, you will examine the operations of a high-speed approach after the initial queue is served using the volume-density gap reduction setting.

Once the Variable Initial interval has expired, and the initial queue has been served, the volume-density gap reduction setting will produce a Vehicle Extension time of 5 seconds, serving vehicles that are slowed as a result of the departing queue. The Vehicle Extension time will then be reduced to a minimum of 3 seconds to efficiently manage the approach operations during the period after the queue has cleared.

You will be viewing a move file that includes two different cases. In the first case, a Vehicle Extension time of 5 seconds is used, while in the second case, the volume-density gap reduction setting is used with the Vehicle Extension time, dynamically reducing the Vehicle Extension time from 5 to 3 seconds. You will observe the effect of each setting on the operation of the EB approach.

## 10.3 Questions to Consider

As you begin this experiment, consider the following questions. You will come back to these questions once you have completed the experiment.

- For which case does the green time extend too long?
- Which case operates more efficiently?
- What is the advantage of using the gap reduction settings?
- Would you suggest any changes to the volume-density gap reduction settings that may improve the efficiency of the operations for case 2?

## 10.4 List of Steps

You will follow these steps during this experiment:

- Open the movie file.
- Observe the operation of the two cases.

## 10.5 Running the Experiment

### Step 1. Open the movie file.

- Locate the “MOST input files” folder.
- Go to the “Lab4” folder, then the “Exp5” folder.
- Open the file: “lab4-exp5.wmv”.

### Step 2. Observe the operation of the two cases.

- In the movie file, you will find windows representing two different cases.
- In the window on the left (case 1), the Vehicle Extension time for the EB approach is set to 5 seconds with no gap reduction setting.
- In the window on the right (case 2), volume-density gap reduction settings are applied to the EB approach.
- Volume-density timing parameters for phase 2 for case 2 are shown in Figure 30.
- Observe the green duration for each cycle in each case.

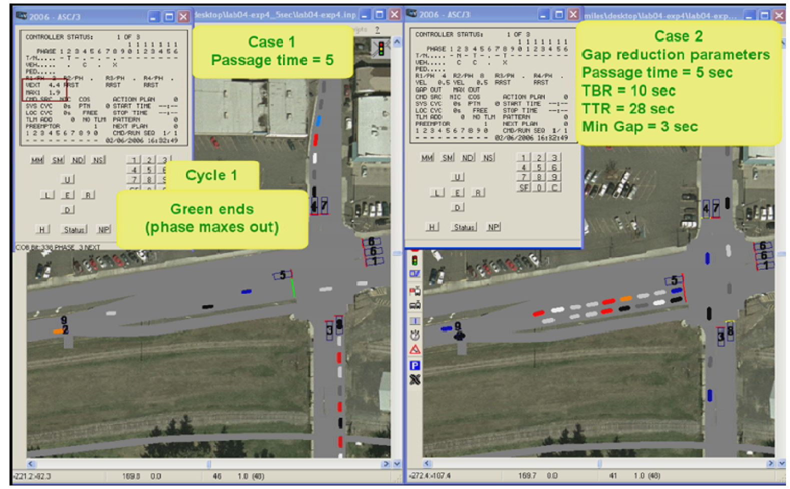
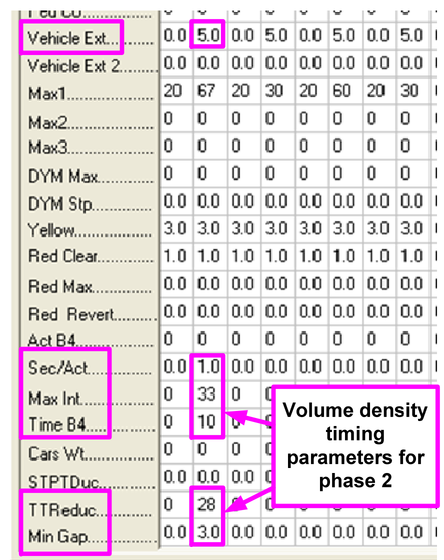



Figure 29 Case 1 and case 2 for Experiment #5




| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Vehicle Ext | 0.0 | 5.0 | 0.0 | 5.0 | 0.0 | 5.0 | 0.0 | 5.0 |
| Vehicle Ext 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Max1 | 20 | 67 | 20 | 30 | 20 | 60 | 20 | 30 |
| Max2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Max3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DYM Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DYM Stp | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Yellow | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Red Clear | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Red Max | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Red Revert | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Act B4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sec/Act | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Max Int | 0 | 33 | 0 | | | | | |
| Time B4 | 0 | 10 | | | | | | |
| Cars Wt | 0 | 0 | 0 | | | | | |
| STPTDuc | 0.0 | 0.0 | 0.0 | | | | | |
| TTReduc | 0 | 28 | | | | | | |
| Min Gap | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Figure 30 Volume-density timing parameters

## 10.6 Discussion

Let's now consider each of the four questions that were presented at the beginning of this experiment.

- For which case does the green time extend too long?
- Which case operates more efficiently?
- What is the advantage of using the gap reduction settings?
- Would you suggest any changes to the volume-density gap reduction settings that may improve the efficiency of the operations for case 2?

Take a few minutes to review each question and write brief answers to each question in the box on the right based on your observations from this experiment.

**Answers to questions:**

In the movie file, you observed two cycles for case 1 and three cycles for case 2. Table 14 shows the results of six cycles for each case starting from cycle 2 and continuing to cycle 7. Table 14 includes the cycle number, the start and end of the green interval, and the duration of the green interval for each cycle for each case. Table 15 again lists the cycle number, the duration of the green interval for each case, and the percent of the Maximum Green time actually used.

### 1. For which case does the green time extend too long?

→In case 1 the green time extends too long. In three of the six cases shown, the phase maxes out. In two other instances, the green time reaches or exceeds 80 percent of the Maximum Green time.

### 2. Which case operates more efficiently?

→Case 2 operates more efficiently than case 1. Why? Table 14 shows the green time duration for each cycle. In nearly every instance the green duration for case 1 exceeds that of case 2. Also, Table 15 shows that the ratio of green duration to the Maximum Green time is nearly always higher for case 2.

Table 14 Time events for phase operation for case 1 and case 2

| Cycle number | Case 1 | | | Case2 | | |
|---|---|---|---|---|---|---|
| | Green begins | Green ends | Duration of green | Green begins | Green ends | Duration of green |
| 2 | 104.7 | 171.7 | 67.0 | 104.7 | 133.1 | 28.4 |
| 3 | 209.7 | 276.7 | 67.0 | 171.1 | 236.6 | 65.5 |
| 4 | 314.7 | 381.7 | 67.0 | 274.6 | 308.1 | 33.5 |
| 5 | 419.7 | 450.7 | 31.0 | 346.1 | 387.5 | 41.4 |
| 6 | 489.8 | 543.3 | 53.6 | 425.5 | 452.2 | 26.7 |
| 7 | 581.3 | 646.7 | 64.3 | 487.1 | 553.8 | 66.7 |

Table 15 Green time duration as a percentage of Maximum Green

| Cycle number | Case 1 | | Case 2 | |
|---|---|---|---|---|
| | Duration of green | Percent of Maximum Green | Duration of green | Percent of Maximum Green |
| 2 | 67.0 | 100 | 28.4 | 42 |
| 3 | 67.0 | 100 | 65.5 | 98 |
| 4 | 67.0 | 100 | 33.5 | 50 |
| 5 | 31.0 | 46 | 41.4 | 62 |
| 6 | 53.6 | 80 | 26.7 | 40 |
| 7 | 64.3 | 96 | 66.7 | 100 |

**3. What is the advantage of using the gap reduction settings?**

→In case 1, the Vehicle Extension time remained constant at 5 seconds. This value caused the green time to be extended inefficiently. In three of the six cycles, the phase actually maxed out (this may cause a significant safety hazard as some vehicles might be in the dilemma zone when the phase terminates). In case 2, the gap reduction setting reduced the initial Vehicle Extension time of 5 seconds linearly to a Minimum Gap of 3 seconds. This provided a more efficient operation as evidenced by the duration of the green time for each interval.

**4. Would you suggest any changes to the volume-density gap reduction settings that may improve the efficiency of the operations for case 2?**

→The operation seems acceptable. The phase gapped out in five cycles out of six. The ratio of the actual green time duration to the Maximum Green time ranged from 42 percent to 100 percent. It might be possible to improve the phase efficiency, by shortening the Time To Reduce parameter or by using a lower value of the Vehicle Extension time or the Minimum Gap.

# 11. EXPERIMENT #6: DESIGN EXERCISE-SETTING VOLUME-DENSITY PARAMETERS

## 11.1 Learning Objective

- Be able to set volume-density timing parameters for a high-speed intersection approach.

## 11.2 Overview

In the previous experiments you learned the value of volume-density timing parameters when advance detection is used on a high-speed approach, specifically the Variable Initial settings and the gap reduction settings. You learned how Variable Initial settings can improve the operational efficiency when queues of varying lengths are present at the beginning of green. You also learned how gap reduction can improve the efficiency after the initial queue has been served.

In this final experiment, you will select the volume-density settings given the speed on one approach of an intersection. You will also assume advance detection on that approach.

While the network is the same as you've previously worked with, the approach speed for the EB approach has been changed to 50 miles per hour. As per Table 2, an advance detector is located 344 feet upstream of the stop bar. This means a maximum of 17 passenger vehicles can be stored between the detector and the stop bar.

## 11.3 Questions to Consider

As you begin this experiment, consider the following questions. You will come back to these questions once you have completed the experiment.

- For advance detection, what problems result when only the Minimum Green time and the Vehicle Extension time are used?
- What effect do the Variable Initial period settings have on operations?
- What effect do the gap reduction settings have on operations?

## 11.4 List of Steps

You will follow these steps during this experiment:

- Start the MOST software tool and open the input file.
- View the controller parameters.
- Observe the simulation using the given timing parameters (without volume-density parameters).
- Determine the Variable Initial period timing parameters.
- Observe the simulation during the Variable Initial period.
- Determine the timing parameters for the gap reduction period.
- Observe the simulation during the gap reduction period.

## 11.5 Running the Experiment

**Step 1. Start the MOST software tool and open the input file**

- Start the MOST software tool and select “Open File.”
- Locate the “MOST input files” folder.
- Go to the “Lab4” folder, then the “Exp6” folder.
- Open the file: “lab4-exp6.inp.”

**Step 2. View the controller parameters**

- Select “Open ASC3 Database Editor.”
- Select controller 2007 in Database Editor.
- The given controller settings for Minimum Green time, Vehicle Extension time, and Maximum Green time (“Max1”) are shown in Figure 31 noted by a “1.”

**Timing Plan (MM) 2-1**

Plan #: 1

| | Phases | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Min Green............ | 5 | 7 | 5 | 5 | 5 | 5 | 5 | 5 |
| | Bk Min Green....... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CS Min Green....... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Delay Green.......... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Walk...................... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Walk2.................... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Walk Max............ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Ped Clear.............. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Ped Clear 2........... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Ped Clear Max...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Ped CO................ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | Vehicle Ext........... | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| | Vehicle Ext 2......... | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Max1.................... | 20 | 50 | 20 | 30 | 20 | 50 | 20 | 30 |

Figure 31 Initial controller settings for Experiment #6

**Step 3. Observe the simulation using the given timing parameters (without volume-density parameters).**

- Start the simulation using the “Run Mode” button.
- Observe the operation of the EB approach, phase 2, for five green intervals. This accounts for a little more than 300 seconds, or five minutes of simulation time.
- Note the queues at the beginning of green on the EB approach.
- Note whether these queues that are present at the beginning of green are served or not.
- Finally, note the operation after the queues are served and whether you think that the service provided is of good quality or not.
- Record your observations in the box at right.

**Observations:**

**Step 4. Determine the Variable Initial period timing parameters.**

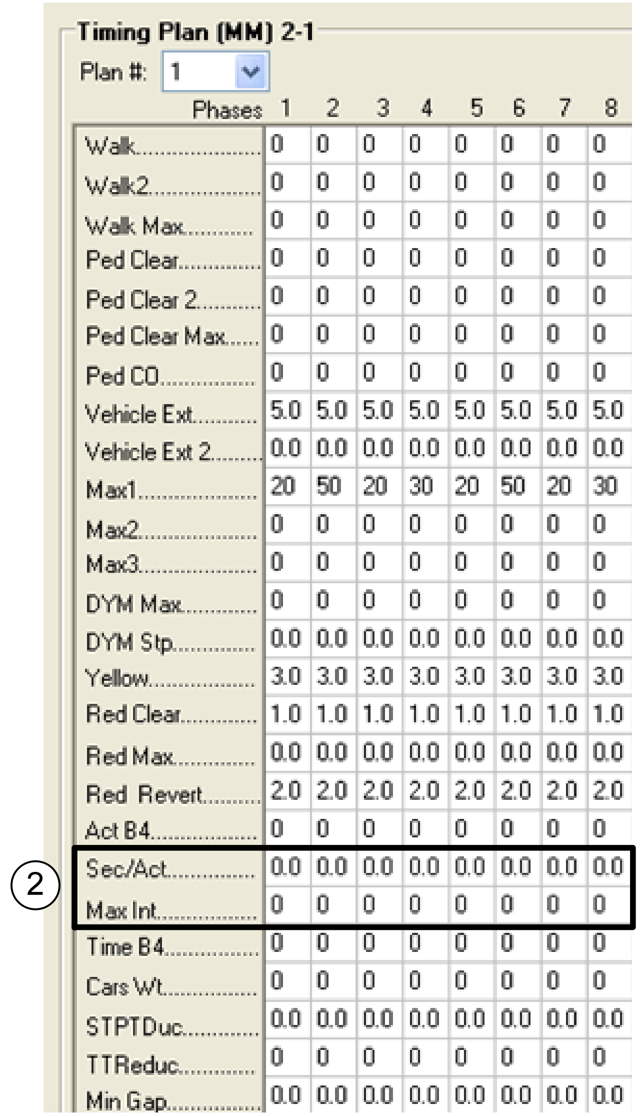
- For volume-density operation, the Variable Initial period is governed by two parameters:
  - Seconds per Actuation
  - Maximum Initial
- Using the information provided in section 5.2 and the knowledge that you have gained, determine the appropriate values for the Seconds per Actuation and Maximum Initial parameters.
- Document the values for these two parameters that you determined and the justification for these values in the box at right.

| **Timing Parameters and Justification:** |
| --- |
| |

**Step 5. Observe the simulation during the Variable Initial period.**

- Enter the values for Seconds per Actuation and Maximum Initial into the Controller Database Editor. These parameters are shown in Figure 32 and noted by the "2."
- Save these values into the database.
- Run the simulation and observe the initial periods, during the time that the queue is clearing. For our purposes here, consider the queue as the queue that formed during red.
- Document your observations in the box below.

**Observations:**


Timing Plan (MM) 2-1

Plan #: 1

| Phases | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Walk | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Walk2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Walk Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped CO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vehicle Ext | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Vehicle Ext 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Max1 | 20 | 50 | 20 | 30 | 20 | 50 | 20 | 30 |
| Max2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Max3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DYM Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DYM Stp | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Yellow | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Red Clear | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Red Max | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Red Revert | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Act B4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sec/Act | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Max Int | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Time B4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cars Wt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| STPTDuc | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TTReduc | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Min Gap | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

2

Figure 32 Variable Initial period timing parameters

**Step 6. Determine the timing parameters for the gap reduction period.**

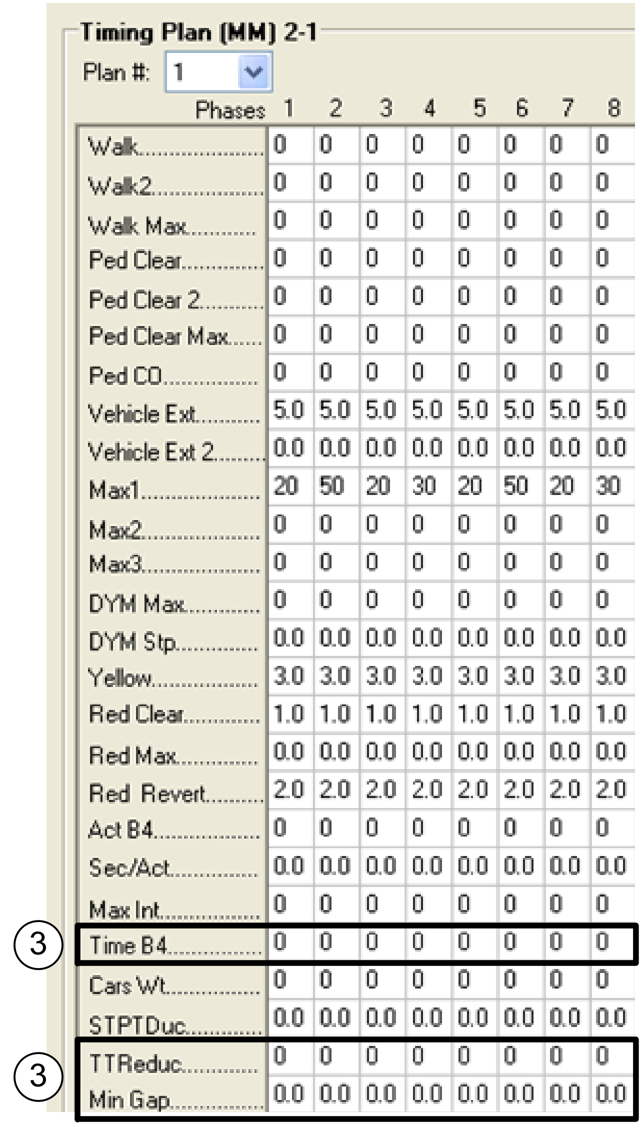
- The gap reduction parameters include the Time Before Reduction, the Time to Reduce, and the Minimum Gap.
- Using the information provided in section 5.2 and the knowledge that you have gained, determine the appropriate values for the Time Before Reduction, the Time to Reduce, and the Minimum Gap parameters.
- Document the values for these three parameters that you determined and the justification for these values in the box at right.

| **Timing Parameters and Justification:** |
| --- |
| |

### Step 7. Observe the simulation during the gap reduction period.

- Enter the values for Time Before Reduction, Time to Reduce, and the Minimum Gap into the Controller Database. These parameters are shown in Figure 33 and noted by the "3."
- Save these values into the database.
- Run the simulation and observe the gap reduction processes, during the time after the queue has cleared. For our purposes here, consider the queue as the queue that formed during red.
- Document your observations in the box below.

**Observations**:




| Phases | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Walk | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Walk2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Walk Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped CO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vehicle Ext | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Vehicle Ext 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Max1 | 20 | 50 | 20 | 30 | 20 | 50 | 20 | 30 |
| Max2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Max3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DYM Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DYM Stp | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Yellow | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Red Clear | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Red Max | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Red Revert | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Act B4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sec/Act | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Max Int | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Time B4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cars Wt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| STPTDuc | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TTReduc | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Min Gap | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Figure 33 Gap reduction timing parameters

## 11.6 Discussion

Let's now consider the questions that were presented at the beginning of this experiment.

- For advance detection, what problems result when only the Minimum Green time and the Vehicle Extension time are used?
- What effect do the Variable Initial period settings have on operations?
- What effect do the gap reduction settings have on operations?

Take a few minutes to review each question and write brief answers to each question in the box on the right based on your observations from this experiment.

**Answers to questions:**

**1. For advance detection, what problems result when only the Minimum Green time and the Vehicle Extension time are used?**

→Let's review the operation with the given conditions: no volume-density timing parameters, only Minimum Green time and Vehicle Extension time. Table 16 presents a summary of the observations for each of the five cycles for the EB approach.

Do your observations match those presented in the table?

Table 16 Observations with given conditions

| Cycle (Start of EB green) | Observations |
|---|---|
| 1 (22.6) | There is a short standing queue at the beginning of green, one vehicle in each lane. The queue clears shortly after the start of green and the phase continues to time for another 20 seconds until it gaps out. |
| 2 (86.0) | There is a standing queue of 11 vehicles in lane 1 and 10 vehicles in lane 2 at the start of green. This standing queue is served. The phase continues to time until the Maximum Green time expires (phase maxes out). Since the Vehicle Extension time is set to 5 seconds, the continued timing of the phase can be considered to be inefficient. |
| 3 (172.2) | There is a standing queue of 7 vehicles in lane 1 and 6 vehicles in lane 2. One of these vehicles is not served as the unoccupancy time at the detector exceeds 5 seconds, even though the standing queue has not been fully served. |
| 4 (206.6) | There is a standing queue of 8 vehicles in each lane. Again, this standing queue is not served. |
| 5 (250.5) | The initial standing queue is served (14-15 vehicles) but Vehicle Extension time of 5 seconds allows vehicles with large headways to be served. |

[Note: The "Start of EB green" shown in the first column above is the simulation clock time, or the time in seconds after the start of the simulation.]

A fixed initial period (no volume-density parameters) results in one problem identified in Table 16: the inability to serve the initial standing queue.

During cycles 3 and 4, the queue doesn't clear before the green ends. There is a need to consider the benefits of volume-density settings, where the initial period can be varied depending on the length of the queue that builds during the previous yellow and red intervals.

Figure 34 shows the standing queue at the start of green for cycle 4. The box shows four vehicles at the end of this queue.

Figure 35 shows the end of green for cycle 4. The same four vehicles are shown in the box and the signal indication has just turned to yellow. A Variable Initial period may help to solve this problem.

Figure 34 Start of green, cycle 4

Figure 35 End of green for cycle 4

A fixed Vehicle Extension time results in another problem identified in Table 16: continued timing of the phase after the initial standing queue has been served.

For cycles 2 and 5, after the initial queue has been served, the phase continues to time even though the headways between vehicles are longer than you would observe in a departing queue. The gap reduction process available in volume-density timing would also help this situation.

Figure 36 shows an example of the phase extending well beyond the end of the queue service time, when headways far exceed a normal maximum allowable headway. While it may be argued that a Vehicle Extension time of 5 seconds may be justified for a high-speed approach when the initial queue is being served (and approximating the travel time from the detector to the stop bar), an inefficient operation does result when headways approach 5 seconds as shown in Figure 36.

Figure 37 shows the variation of headways during cycle 2 after the initial standing queue has cleared at both the stop bar (solid line) and at the detector (dashed line). Several headways exceed 3 seconds, and in four cases, the headways exceed 4 seconds. There is clearly a need to have a lower Vehicle Extension time during this period of the green interval.

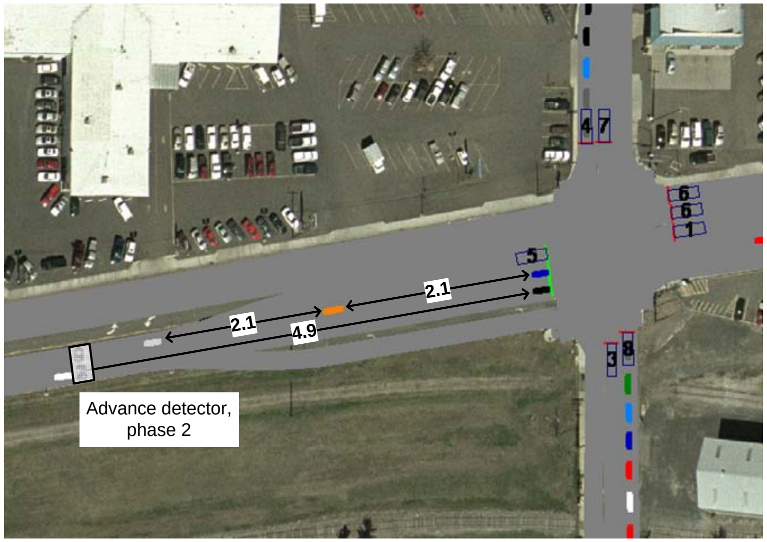


Figure 36 Headways at end of green, cycle 2

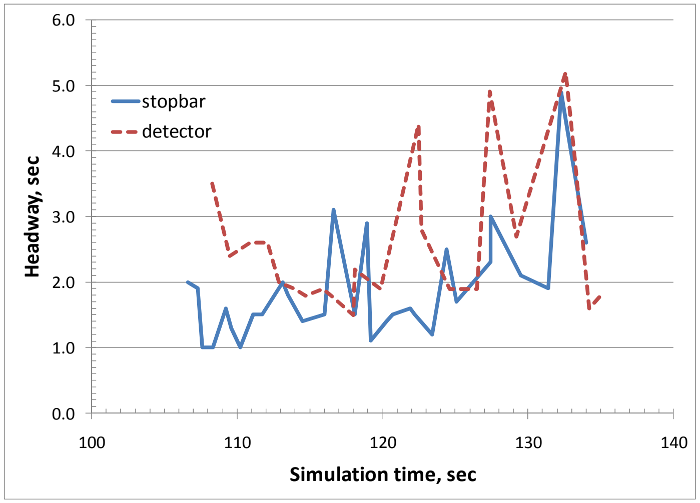


Figure 37 Headways at the end of cycle 2

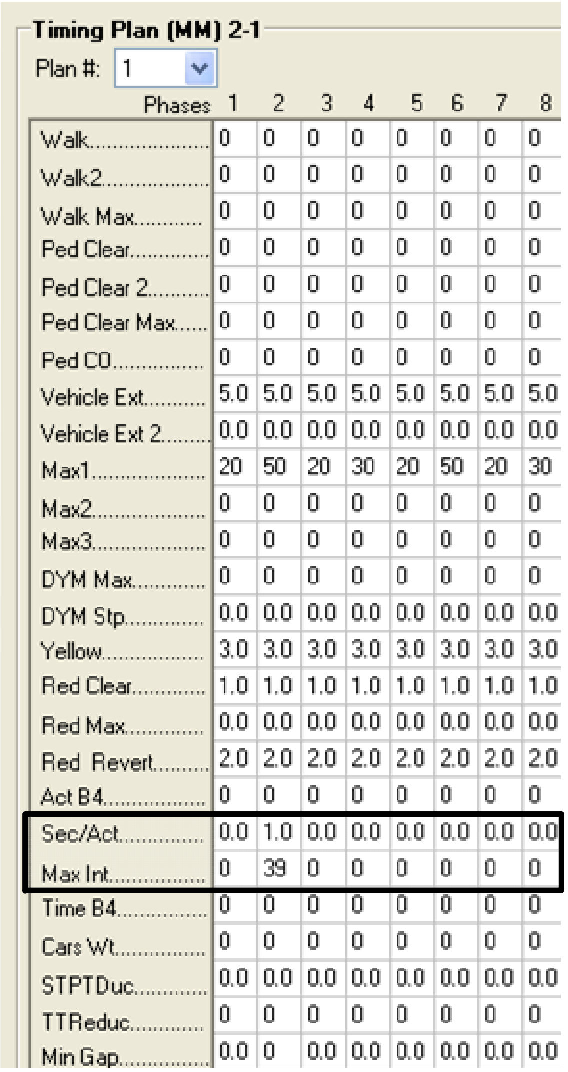
**2. What effect do the Variable Initial period settings have on operations?**

→The Variable Initial period settings are Seconds per Actuation and Maximum Initial.

Figure 15 (page 191) provides recommended values of Seconds per Actuation as a function of the distance to the advance detector and the number of lanes. In this problem, the advance detector is located 344 feet from the stop bar and approach detection is used. Using the figure, the Seconds per Actuation would be 1.2 seconds in the case of mixed traffic. In this case (passenger cars only) 1.0 second would provide adequate green time to serve the queue.

Similarly, Figure 14 (page 190) shows recommended values for the Maximum Initial, also as a function of the distance between the advance detector and the stop bar. Using the figure, the Maximum Initial would be 39 seconds. This value provides sufficient time for a queue just shorter than this distance to be served before the green would be terminated.

Figure 38 shows these parameters after they have been entered into the controller database.



Timing Plan (MM) 2-1

Plan #: 1

| Phases | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Walk | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Walk2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Walk Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped Clear Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped CO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vehicle Ext | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Vehicle Ext 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Max1 | 20 | 50 | 20 | 30 | 20 | 50 | 20 | 30 |
| Max2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Max3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DYM Max | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DYM Stp | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Yellow | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Red Clear | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Red Max | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Red Revert | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Act B4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sec/Act | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Max Int | 0 | 39 | 0 | 0 | 0 | 0 | 0 | 0 |
| Time B4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cars Wt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| STPTDuc | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TTReduc | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Min Gap | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Figure 38 Variable Initial period timing parameters

Figure 39 shows the queue beginning to move on the EB approach at the start of green for cycle 3, after the Sections per Actuation has been set to 1.0 seconds and the Maximum Initial has been set to 39 seconds, using the methodology described on the previous page.

During the previous yellow and red intervals, 14 vehicles arrived on the EB approach, forming the queue that is visible in the figure. The 14 vehicles registered 14 detector calls, which result in a Variable Initial period of 14.0 seconds (the product of 14 vehicles and 1.0 seconds per vehicle).

Figure 40 shows the queue moving just after the Minimum Green timer has expired and the Added Initial timer begins to time. This occurs 7 seconds after the beginning of green at t = 179.2. Four vehicles from the queue have entered the intersection.


Figure 39 Beginning of phase 2 green (cycle 3) with Variable Initial settings


Figure 40 Queue at t = 179.2 when Added Initial begins to time

At t = 186.9, the standing queue has cleared, and the Added Initial timer has just expired. This is shown in Figure 41.

So, our computed time for the Seconds per Actuation (1.0 seconds) achieves the goal of serving the initial queue. Without volume-density timing we couldn't successfully serve the standing queue when advance detection is used. Using the Variable Initial timing parameters, the standing queue is served.

Another problem, though, persists. While the initial standing queue is served, certainly an improvement over our first run, the phase continues to time even with headways exceeding 3 and 4 seconds! In fact, 22 vehicles are served after the queue has cleared.

In the next iteration of our design, we will introduce the gap reduction parameters and see what effect they have on the operation.

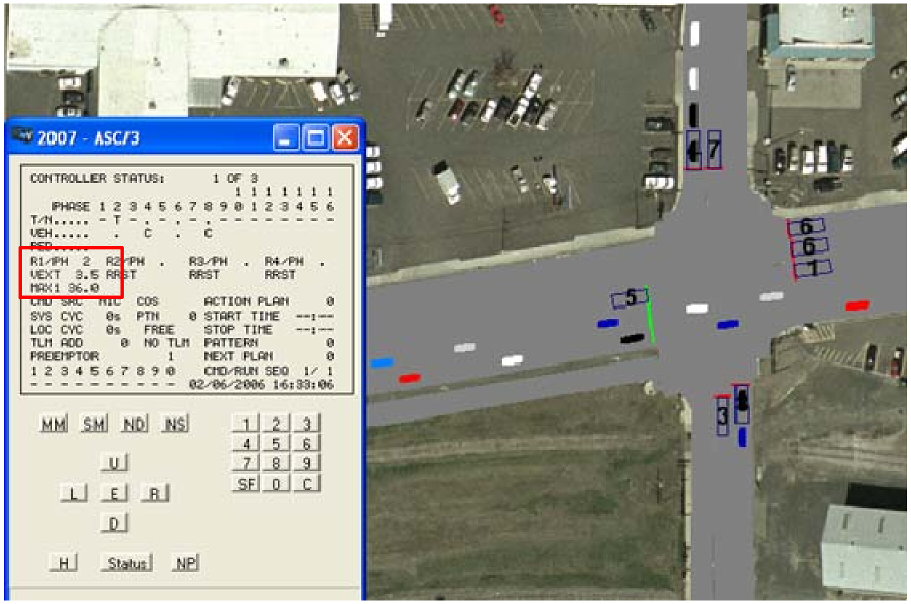


Figure 41 Queue clears at t = 186.2

### 3. What effect do the gap reduction settings have on operations?

→To improve the efficiency of the operation, the following time parameters were set:

- Time Before Reduction = 10 seconds
- Time To Reduce = 20 seconds
- Minimum Gap= 2 seconds

Let’s consider the results from cycle 2. The green interval begins at t = 86.0 seconds after the start of the simulation. There are 21 vehicles in the queue at the start of green, 11 in lane 1 and 10 in lane 2. See Figure 42.

As before, the queue is served because of the Variable Initial parameters (Seconds per Actuation and Maximum Initial). But the phase continues to time with a Vehicle Extension time of 5 seconds.

Figure 42 Queue at beginning of green, t = 86.0

The Variable Initial timing processes are shown in Figure 43. The Minimum Green timer begins at the start of the green interval and expires seven seconds later. The Added Initial timer also begins to time at the beginning of green. However, in the ASC/3 status display, it does not appear until after the Minimum Green timer has expired.

The gap reduction process also begins at the beginning of the green (t = 83.9) when a call is received on a conflicting phase. When this conflicting call is received, the Time Before Reduction process begins. The Time Before Reduction timer expires 10 seconds after it begins, at t = 93.9.

At this point (t = 93.9), the Gap in Effect is reduced, beginning at the Vehicle Extension time value of 5 seconds. It will be reduced linearly over a period of 20 seconds (the Time to Reduce) until the Minimum Gap time of 2 seconds is reached. This process is shown in Figure 44. The reduced gap (displayed as Gap in Effect in the ASC/3 controller display) means that the phase terminates in a more efficient manner.

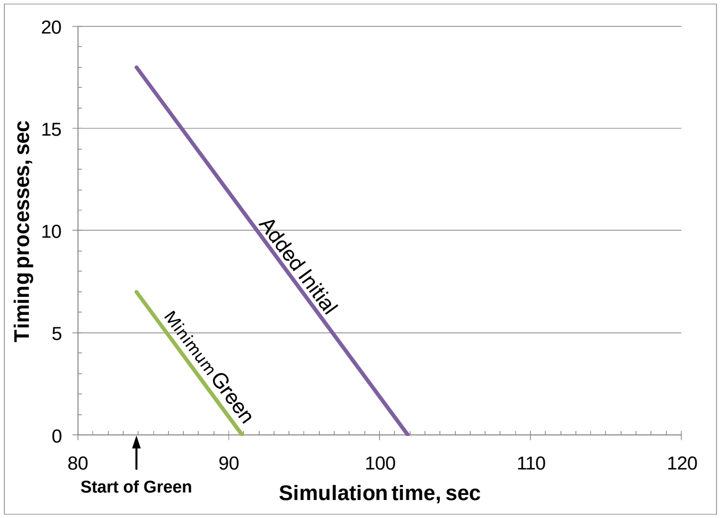



Figure 43 Variable Initial timing processes, cycle 2

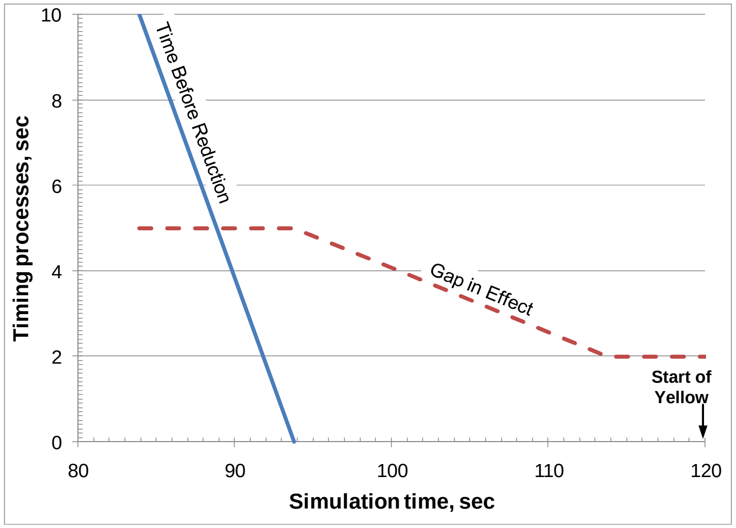



Figure 44 Gap Reduction timing process, cycle 2

# 12. CLOSURE: SUMMARY OF KEY POINTS LEARNED

In Laboratory 4, you examined the operations of a high-speed approach using advance detection (and no stop bar detection). You learned that the location of the detector must be considered together with other parameters such as operating speed and stopping distance. You also learned to relate control parameters such Minimum Green and minimum Vehicle Extension time to the detector location. Finally, you learned how volume-density parameters can be used to improve the efficiency of the signal timing at a high-speed approach.

In previous laboratories, we assumed fixed or static values for the Minimum Green time and Vehicle Extension time. In Laboratory 4, we investigated how Variable Initial periods (and dynamically computed initial times) and variable extensible periods could improve intersection operations. In the final experiment of Laboratory 4, you developed a timing design based on what you learned about these two timing periods.

In Laboratory 5, you will learn how various left turn phasing plans affect intersection operations.