CHAPTER

4 Actuated Traffic Controller Timing Processes

Purpose

In Chapter 4, you will learn about the timing processes that run an actuated traffic controller. Many transportation engineers begin their study of signalized intersections by making assumptions on the length of the cycle and the duration of the green intervals for each phase. However, the reality is the cycle length and the green interval durations are the result of the interaction of the traffic demand and a set of actuated controller timing processes. If the demand is low, the phase may only last until the minimum green timer has expired; but if the demand is high, the phase may be extended (by a series of intervals equal to the vehicle extension time for each vehicle that arrives at the intersection) until the maximum green time has been reached. Thus the green duration and the cycle length will vary as the demand varies from one cycle to the next.

The Highway Capacity Manual or HCM (Transportation Research Board, 2010) includes a method for synthesizing the green interval duration based on demand and some of the timing parameters described in this section. However, in order for you to develop a signal timing plan, it is important for you to understand these actuated controller timing parameters and the process followed by each.

Learning Objectives

When you have completed the activities in this chapter, you will be able to

- Describe the actuated controller timing processes
- Complete a traffic control process diagram describing the response of the detectors, the timing processes, and the displays to a pattern of vehicle demand
- Describe the range of information provided in the ASC/3 controller
- Describe the effect of detector calls on controller timing processes
- Describe the two primary methods of terminating a traffic phase at an isolated intersection
- Describe the actuated controller timing processes
- Infer signal timing parameter values through field observations
- Contrast the signal timing terms that are presented in this chapter with those described in the *Traffic Signal Timing Manual*

Chapter Overview

This chapter begins with a *Reading* (Activity #17). The reading describes and illustrates the three basic actuated controller timing processes, establishing your initial knowledge base of these processes. This reading covers the minimum green time, the passage time, and the maximum green time. Each of these three is a timing parameter, the value of a timing parameter, and a timing process. In Activity #18, you will assess your understanding of the material presented in the *Reading* by constructing three traffic control process diagrams. In Activity #19, you will study the ASC/3 traffic controller to learn about how basic actuated timing processes operate and are displayed in the controller front panel. In Activity #20, you will use a side-by-side movie of a VISSIM simulation to observe the two different ways in which a phase first times and then terminates. Activity #21 leads you through additional studies of the traffic controller and its timing processes using an emulator run in an Excel spreadsheet. In Activity #22, you will continue to test your understanding of various traffic conditions and timing parameters by constructing a series of traffic control process diagrams, each illustrating a basic concept of signal timing. You will collect field data in Activity #23 to infer the values of the three signal timing parameters. The chapter concludes with Activity #24, in which you will link what you have learned in the chapter with material from the *Traffic Signal Timing Manual*.

Activity List

Number and Title	Type
17 Controller Timing Process	*Reading*
18 What Do You Know About Controller Operations?	*Assessment*
19 The ASC/3 Traffic Controller	*Discovery*
20 How a Traffic Phase Times and Terminates	*Discovery*
21 Exploring a Controller Emulator	*Discovery*
22 Constructing a Traffic Control Process Diagram	*Discovery*
23 Inferring Signal Timing Parameter Values	*Field*
24 Signal Timing Parameters	*In Practice*

ACTIVITY

17 Controller Timing Process

READING

Purpose

The purpose of this activity is to give you the opportunity to learn more about basic actuated controller timing processes.

Learning Objective

- Describe the actuated controller timing processes

Deliverables

- Define the terms and variables in the Glossary
- Prepare a document that includes answers to the Critical Thinking Questions

Glossary

Provide a definition for each of the following terms. Paraphrasing a formal definition (as provided by your text, instructor, or another resource) demonstrates that you understand the meaning of the term or phrase.

gap out	
max out	
maximum green	
minimum green	
passage time	

CRITICAL THINKING QUESTIONS

When you have completed the reading, prepare answers to the following questions.

1. What are the two types of phase termination and what are the factors that result in each of these two types?

2. What happens if the passage timer expires before the minimum green timer expires?

3. What is a *traffic control process diagram* and what processes does it illustrate?

INFORMATION

In Chapter 1, you were introduced to the traffic control process diagram. This diagram, which is represented in Figure 73, shows the four processes or components of the traffic control system and how they interrelate:

1. The user arrives at the intersection and is detected.
2. The detector sends a call to the traffic controller.
3. The controller determines the signals to display.
4. The user responds to the signal that is displayed, shown with the feedback loop on the left of Figure 73.

In this chapter, you will learn about the three most important timing processes that govern the operation of the actuated controller, and the logic that is used to determine how long a phase remains active ("is timing") and when and how the phase will terminate.

Let's first define these parameters and the process that each follows. It should be noted that we will describe both a timing parameter and a process, each with the same name. This may seem a bit confusing at first!

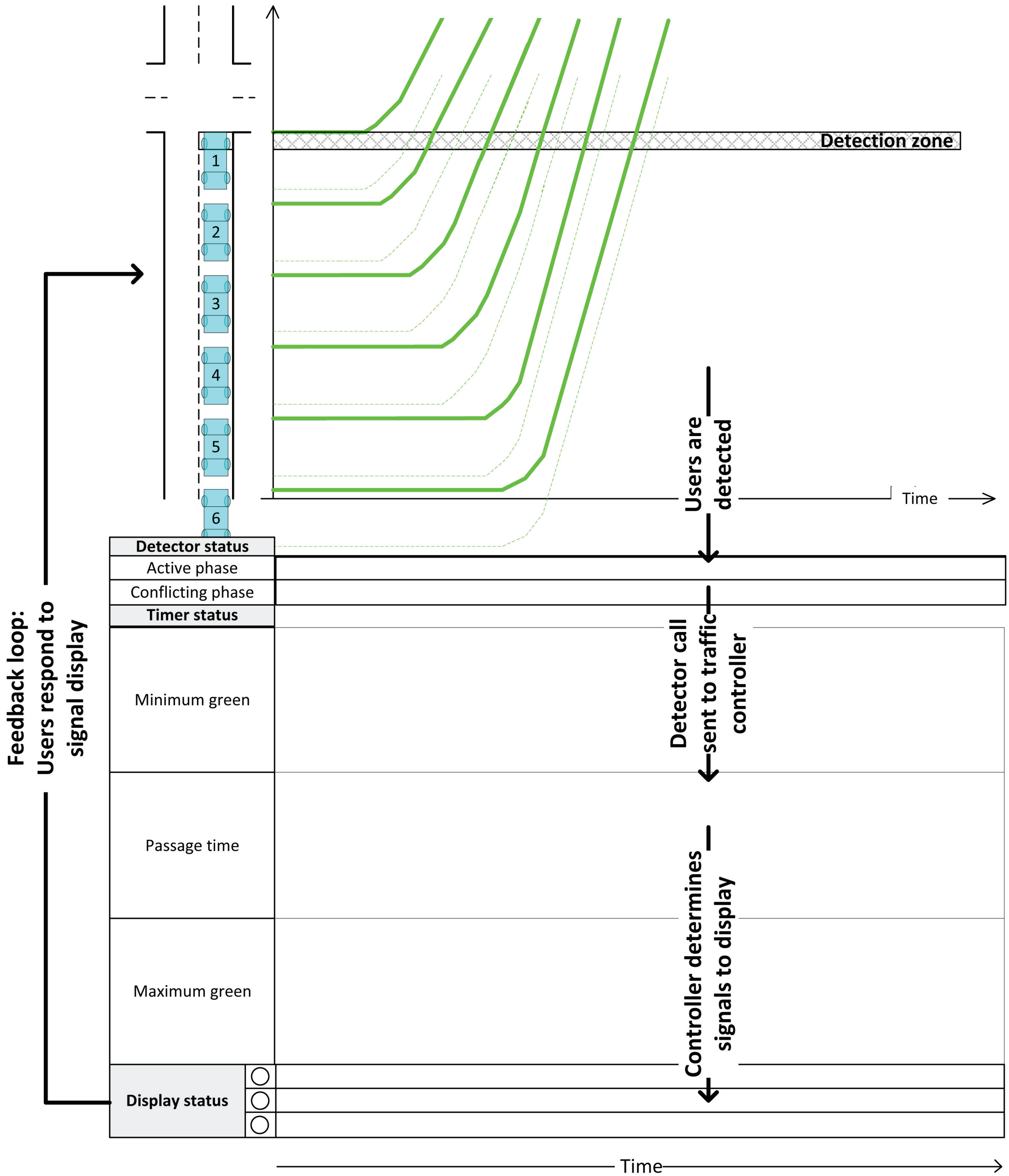


Figure 73. Traffic control process diagram

The minimum green time is the minimum time that the display will remain green for a phase no matter what else occurs. The minimum green timer is initially set to a value equal to the minimum green time. When the phase begins timing, the minimum green timer begins to time down and it expires when its value reaches zero, as shown in Figure 74. You will learn more about determining the length of the minimum green time in Chapter 6.

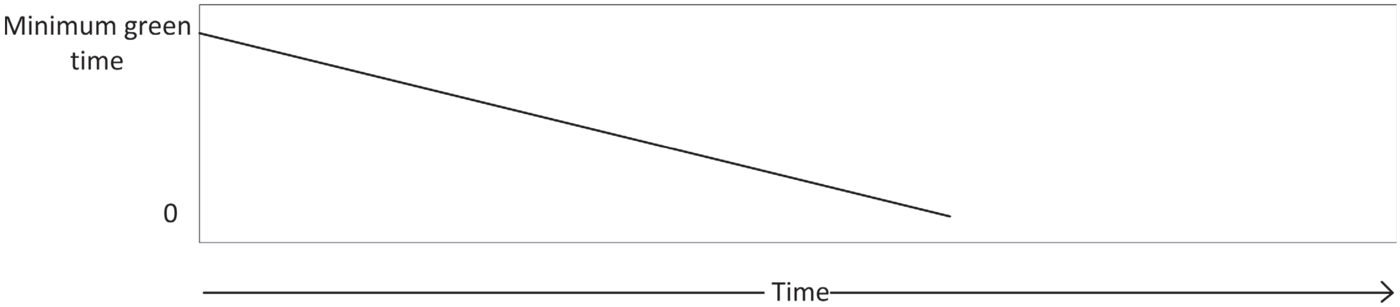


Figure 74. Minimum green timer process

The purpose of the passage timer (sometimes called the vehicle extension timer) is to extend the green until a gap of a pre-determined size is reached. The passage time is the maximum time that a detector can remain unoccupied before the passage timer expires. The significance of the relationship between the passage time and the maximum allowable headway will be described in Chapter 6. As long as a vehicle remains in the detection zone (or, "a call is active"), the timer will remain at its initial value or setting. Once a vehicle leaves the zone, the timer begins to time down. When a subsequent vehicle enters the zone, the timer is reset to its initial value. We will see in Chapter 6 the relationship of the passage time to the maximum allowable headway, the maximum headway that we will tolerate before allowing the phase to terminate. We will also see that this relationship is dependent on the length of the detection zone.

The following figures show example timing processes for the passage timer. In Figure 75, the passage timer begins to time down when a vehicle leaves the detection zone. In this example, it expires because no subsequent vehicle resets the timer.

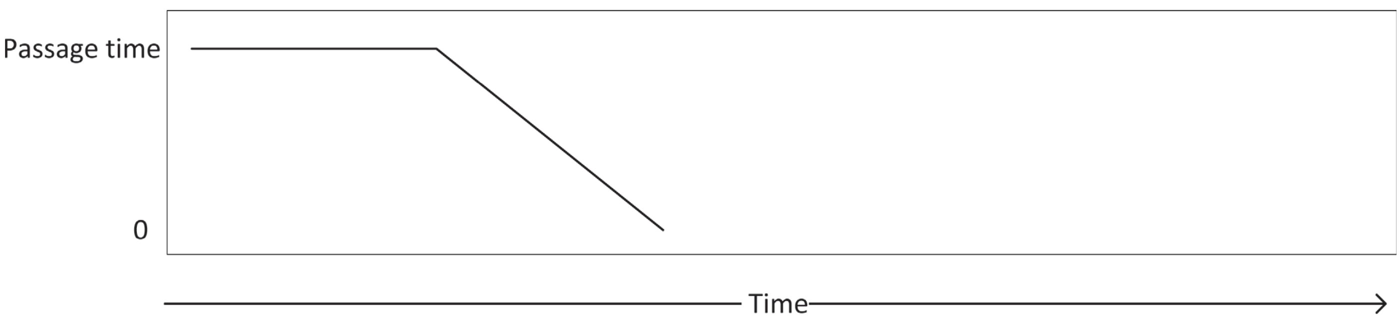


Figure 75. Passage timer process

By contrast, in Figure 76, the passage timer is reset several times, as one vehicle leaves the zone and a subsequent vehicle arrives in the zone, before the timer reaches zero.

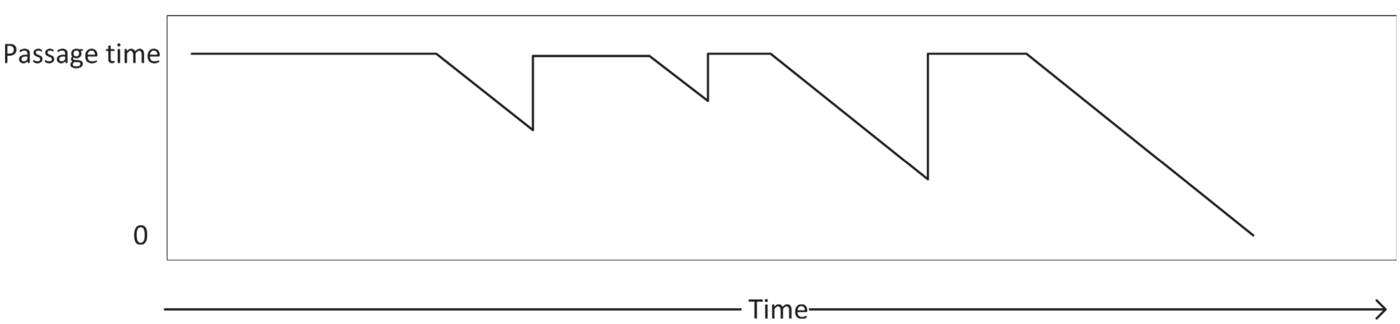


Figure 76. Passage timer process

The purpose of the maximum green time is to produce a maximum cycle length that keeps delay at a reasonable level. The maximum green time is the maximum duration that the signal display will remain green after a call has been received on a conflicting phase. When such a call is received, the timer will begin to time down and continue until it reaches zero as shown in Figure 77. You will learn more about setting the value for the maximum green time in Chapter 7.

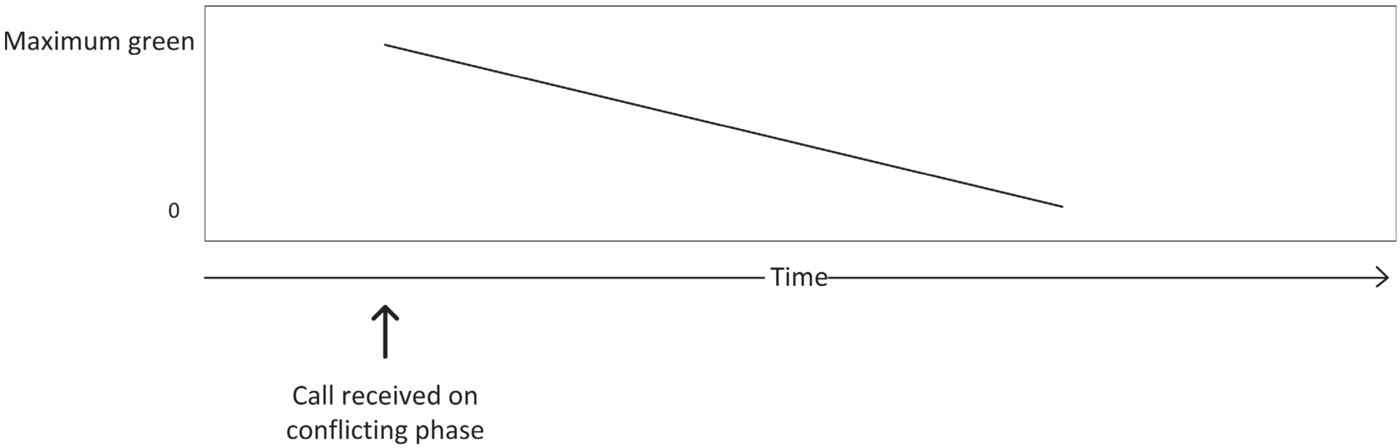


Figure 77. Maximum green timer process

The phase termination logic in a controller determines how long a phase will time and when it will terminate. The timing and termination logic is covered in more detail in Chapter 6 of this book. For standard actuated traffic control, a phase will continue to time until one of two possible events occur, either a gap out or a max out.

A gap out occurs when both the minimum green timer and the passage timer have expired. An example of a gap out is shown in Figure 78. While the maximum green timer is still active and timing down, once the passage timer expires, the phase will gap out.

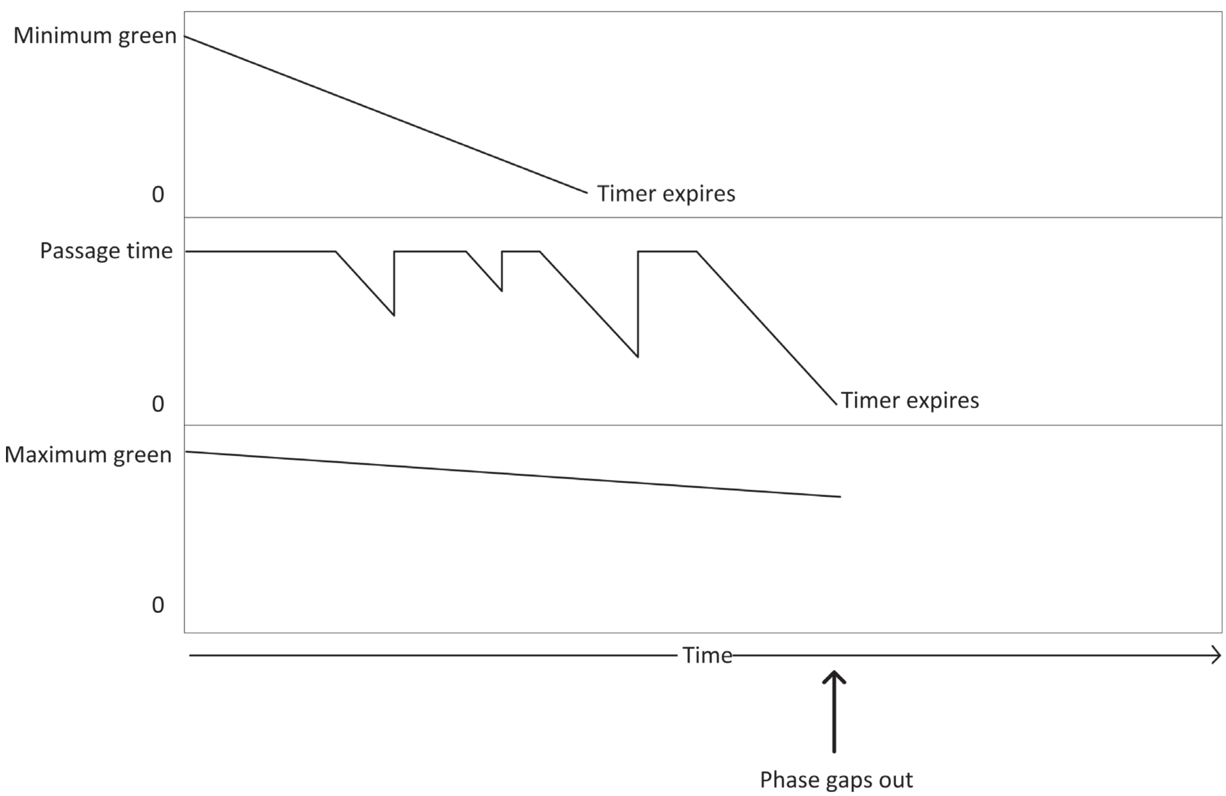


Figure 78. Example of gap out

A max out occurs when the maximum green timer expires. An example of a max out is shown in Figure 79. While the minimum green timer has expired, continuing demand extends the passage timer, as it resets each time a new vehicle is detected. However, the phase terminates when the maximum green timer expires.

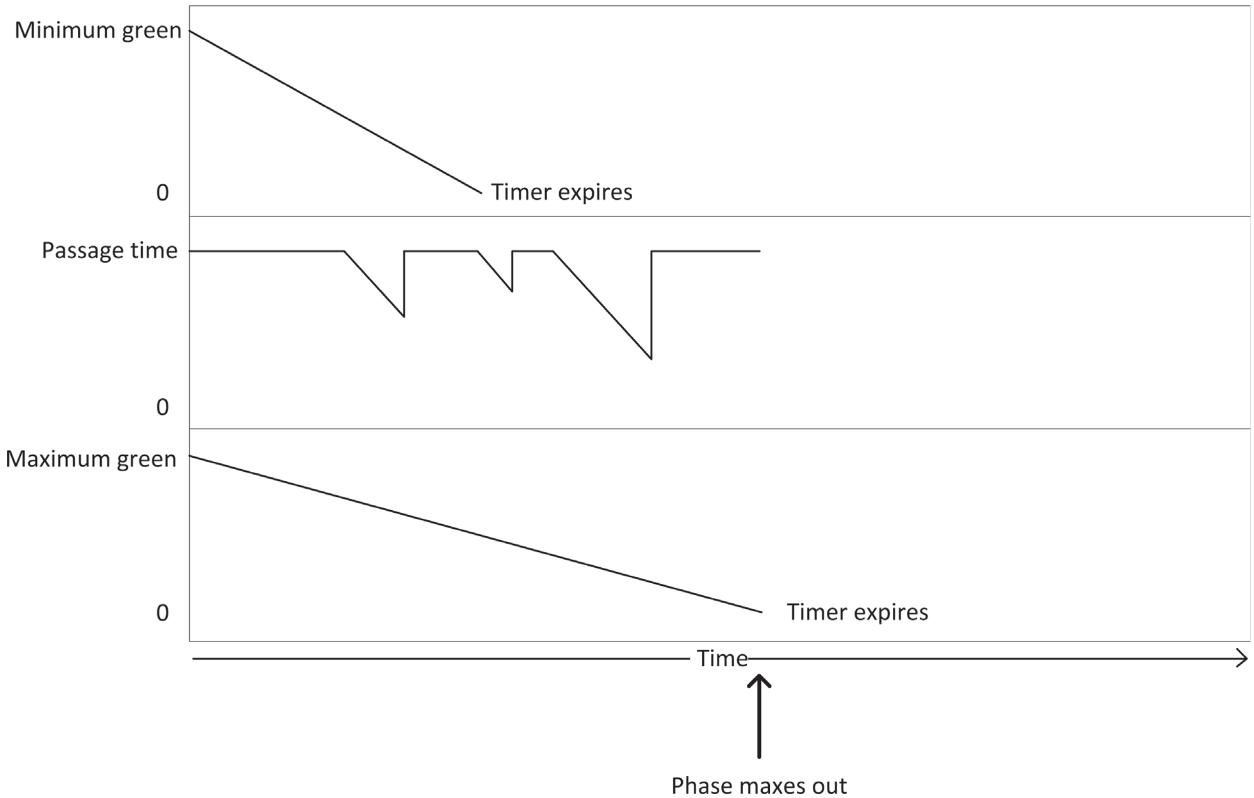


Figure 79. Example of max out

ACTIVITY

18 What Do You Know About Controller Operations?

ASSESSMENT

Purpose

The purpose of this activity is to test your understanding of the basic timing processes for an actuated traffic controller.

Learning Objective

- Complete a traffic control process diagram describing the response of the detectors, the timing processes, and the displays to a pattern of vehicle demand

Deliverable

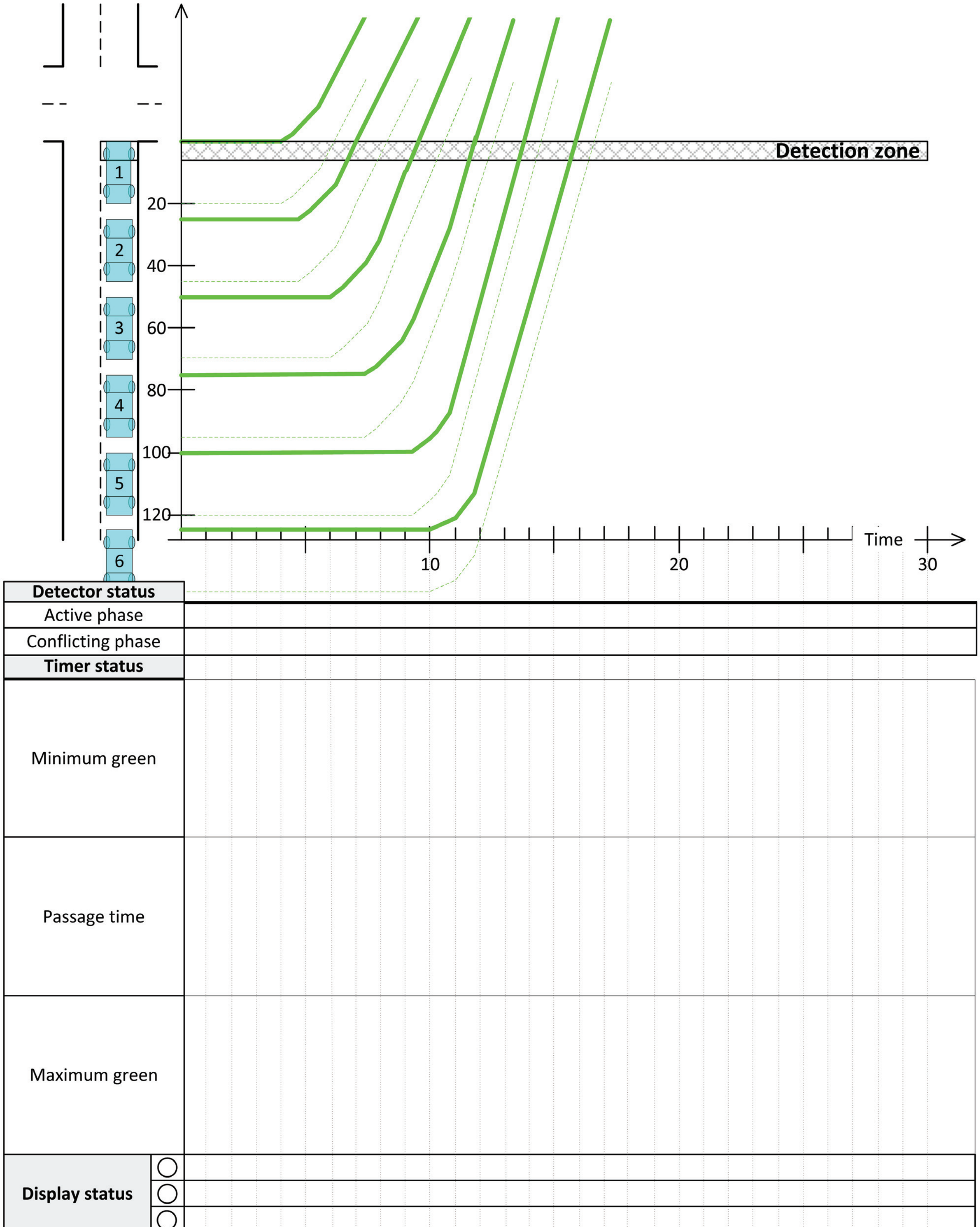
- Prepare a document with copies of the completed charts as required from Tasks 1 and 2

Task 1

The traffic control process diagram (Figure 80, following page) shows the vehicle trajectories in a time space diagram format as well as the timing parameter values (bottom right of figure). Draw the detector status, the timer status, and the display status. Show the graphs for the values of the three timing processes in the spaces provided, noting the maximum and minimum values of the processes on the y-axis. The resulting signal display may change some of the vehicle trajectory plots. Note on the figures where you think that these changes will occur. Assume a yellow time of 3 seconds. Assume that the green time starts at $t = 0$. Also assume that the conflicting call begins at $t = 0$ and continues throughout the green duration.

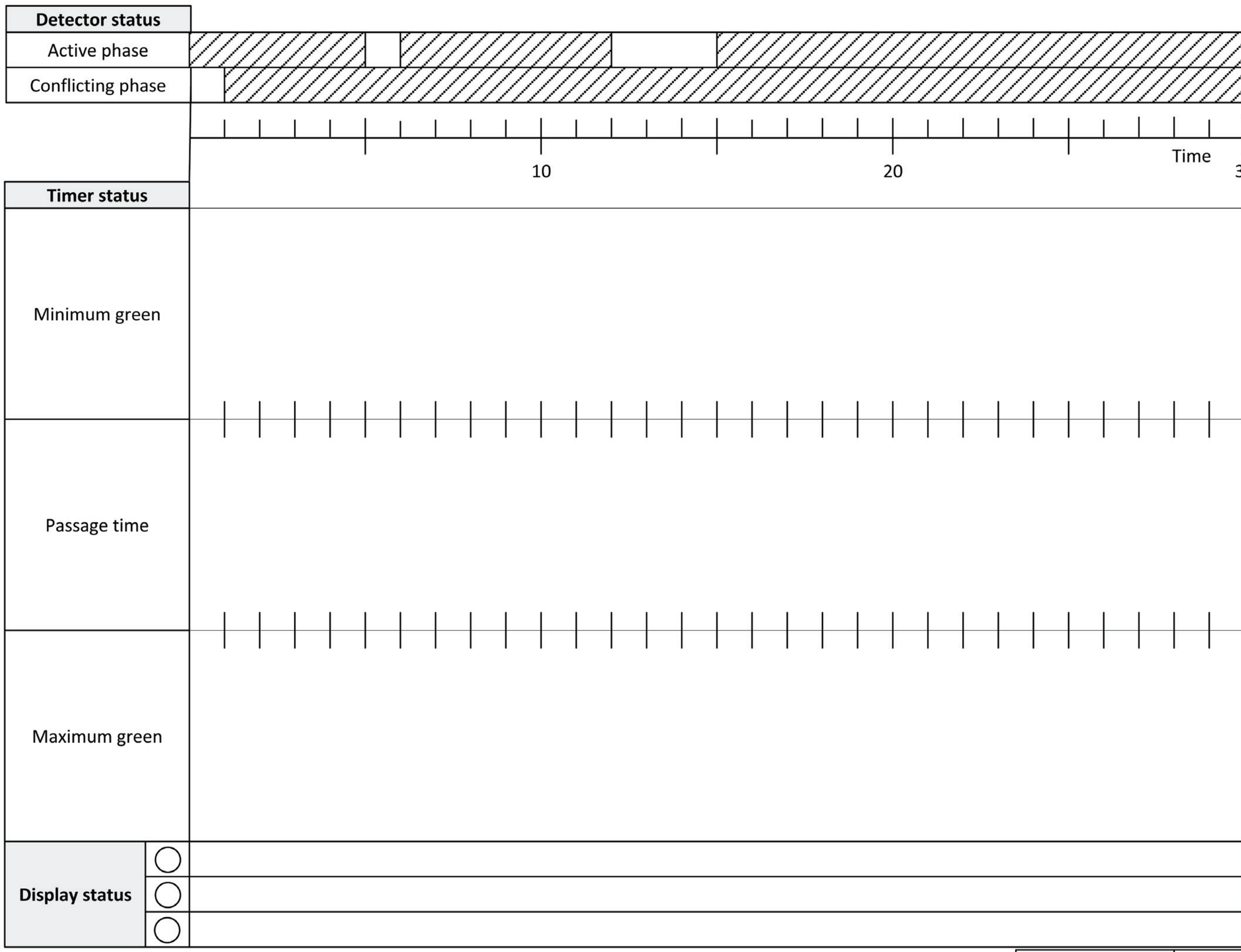
Task 2

Figure 81 and Figure 82 (see following pages) show traffic control process diagrams without the vehicle trajectories, but with the detector status data for both the active and the conflicting phases. The values of the timing parameters are given in the lower right of the two figures. Show the resulting timing processes in the form of a chart showing the value of the timing parameter as long as the green is active for that phase. Show the resulting signal display status, noting only when the display changes. State how the phase terminates in each case. Assume a yellow time of 3 seconds. Assume that the green time starts at $t = 0$.



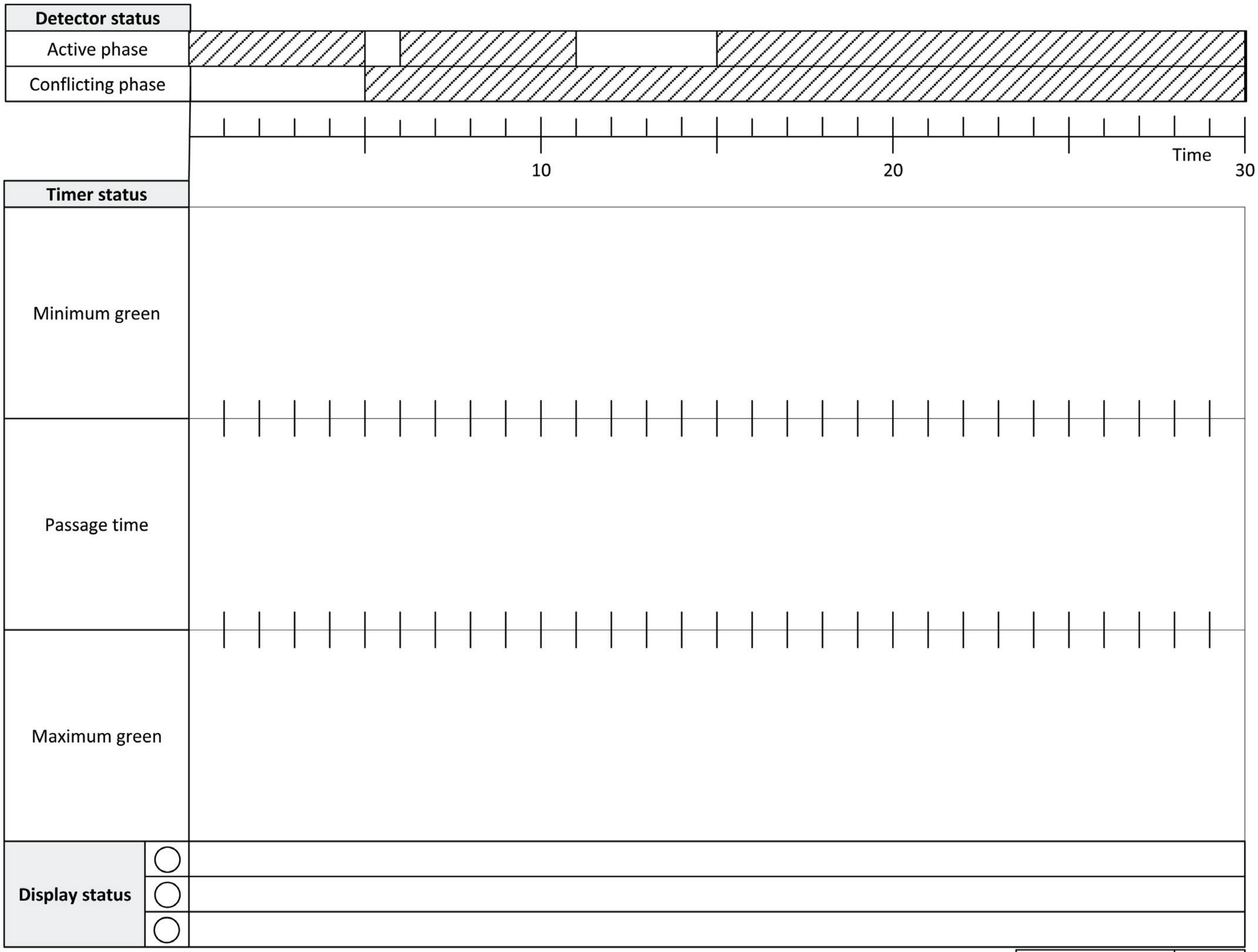
Min green	3s
Passage time	3s
Max green	20s

Figure 80. Traffic control process diagram with vehicle trajectories



Min green	0s
Passage time	2s
Max green	15s

Figure 81. Traffic control process diagram



Min green	5s
Passage time	0s
Max green	12s

Figure 82. Traffic dontrol process diagram

ACTIVITY

19 The ASC/3 Traffic Controller

DISCOVERY

Purpose

The purpose of this activity is to give you the opportunity to learn more about the operation of an actuated traffic controller.

Learning Objectives

- Describe the range of information provided by the ASC/3 controller
- Describe the effect of detector calls on controller timing processes

Required Resource

- Movie file: A19.mp4

Deliverable

- Prepare a document that includes your answers to the Critical Thinking Questions

Critical Thinking Questions

1. What are examples of the data provided in the controller status display screen?

2. How many rings can be accommodated by the ASC/3 controller?

3. How do you know whether a gap out or a max out has occurred?

4. How can you verify that a vehicle call has been placed?

5. Describe some of the observations that you have made on the response of the controller timing processes to vehicle calls.

Information

There are a number of traffic controllers that are in common use today, including those manufactured by McCain, Siemens, Peek, Naztec, and Econolite. There are three primary types, Type 170 and 2070 controllers, NEMA controllers, and advanced traffic controllers (ATC). In this activity, you will discover (explore) a NEMA controller produced by Econolite known as the ASC/3.

The features and functions of the ASC/3 are not dramatically different from other actuated traffic controllers. Using the ASC/3 controller emulator, including its functionality and the kinds of information that it displays, will help you to understand more about traffic signal timing and the controller processes that determine how effective a timing plan will be. While other types of controllers are used in this book, the ASC/3 controller emulator provides a transparent way to learn more about traffic controllers in general.

The video that you will watch as a part of this activity shows the ASC/3 controller in operation (see Figure 83). The left portion of Figure 83 shows the display for a tool that is commonly used to test the functions of a traffic controller known as a "suitcase tester." This tester derives its name because it is often stored in a suitcase box for easy portability. The display status for each vehicle phase is shown at the top of the screen (green, yellow, red). In this example, phase 2 is currently green while the other phases display red. Detector calls can be placed by clicking on the boxes at the bottom of the left portion of the screen (where the cursor is shown in the figure).

The right portion of the figure shows the status display screen for an ASC/3 controller, as you would see it in the lab or in the field. For each phase, you can see the phase status and the presence (or not) of a vehicle call. Phase 2 is currently active ("G" for green). You can also observe the status for various timers for rings 1 and 2, and as well as the phase that is currently active. Here, phase 2 is timing in ring 1 and the vehicle extension timer (EXT1) is at 2.8 seconds. The maximum green timer (MAX1) is at zero.

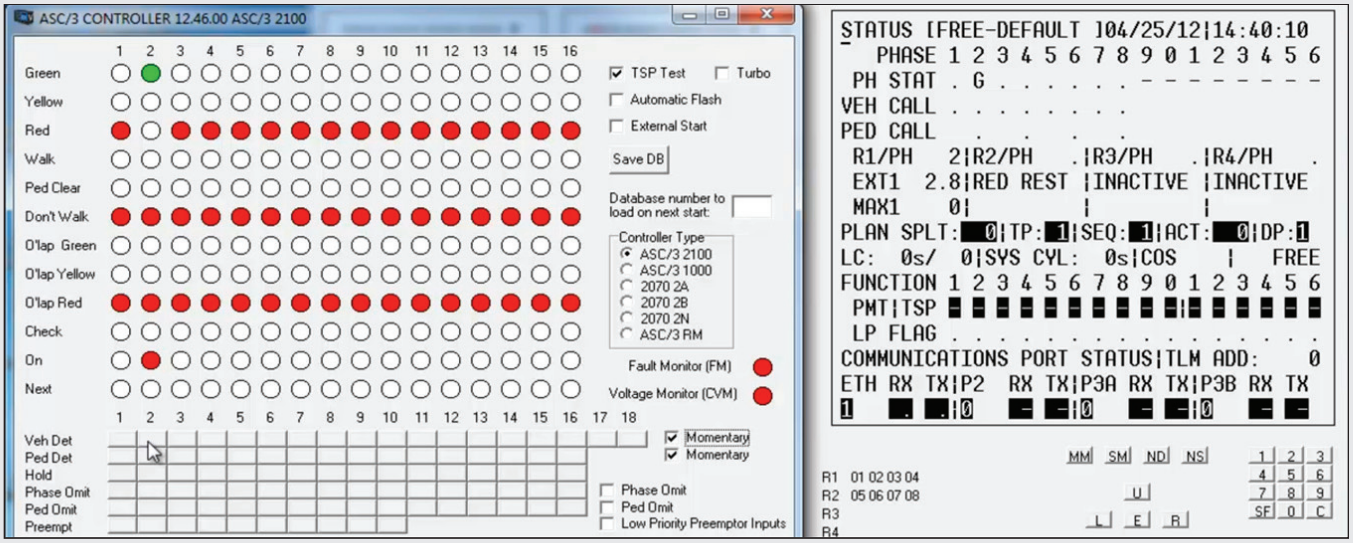


Figure 83. ASC/3 controller

TASK 1

Open the movie file A19.mp4. Watch it from the beginning through *t* = 0:55. Familiarize yourself with both the suitcase tester display (on the left portion of the video screen) and the controller status display screen (on the right side of the video screen). Take notes on what you observe and record these notes in Table 9 (see the following page).

TASK 2

The video from *t* = 0:58 to *t* = 2:30 shows a series of actions (detector calls placed) and responses (timing process changes). For the first part of this segment (0:58 – 1:12) constant calls are placed on phases 2, 4, 6, and 8. For the second part (1:13 – 1:20), there are responses to these calls. Take notes on the responses that you observe.

TASK 3

From *t* = 2:40 to *t* = 5:00, there are a series of detector calls placed and controller responses that result. Closely observe the four segments in this time interval and record the controller responses that you observe in Table 9.

TASK 4

Document your answers to the Critical Thinking Questions.

Table 9. ASC/3 controller observations

Video time interval	Detector calls	Controller responses/other notes
0:00 – 0:55		
0:58 – 1:12		
1:13 – 1:20		
2:40 – 3:00	Call on phase 2 at *t* = 2:55	
3:15 – 3:30	Calls on phases 4 and 8 at *t* = 3:21 – 3:23	
3:30 – 3:40	Call on phase 2 at *t* = 3:37	
3:40 – 4:40	Calls on phases 2, 4, and 6 between *t* = 3:46 and 4:35	

ACTIVITY
20 How a Traffic Phase Times and Terminates

DISCOVERY

Purpose

The purpose of this activity is to give you the opportunity to observe the timing of a traffic phase and the method by which the phase terminates.

Learning Objective

- Describe the two primary methods for the termination of a traffic phase at an isolated intersection

Required Resource

- Movie file: A20.wmv

Deliverable

- Prepare a document that includes answers to each Critical Thinking Question based on your observations from this activity

Critical Thinking Questions

1. Why does the phase terminate for each of the two cases that you observe?

2. What is the process followed by the minimum green timer from the beginning of the green indication, until the timer expires?

3. What is the process followed by the vehicle extension timer from the beginning of the green indication, until the timer expires?

4. What is the process followed by the maximum green timer from the beginning of the green indication, until the timer expires?

5. What are the two conditions that separately cause the termination of the green indication?

6. Reflect on what you have observed on how a phase terminates. Write a summary of your observations.

Information

You will observe the southbound approach (phase 4) of the intersection of State Highway 8 and Line Street. This approach (Line Street) has two lanes, a left turn lane and a through/right turn lane. State Highway 8 is the major street and serves as a primary east-west route through the city. It also serves as the major access to a university. See Figure 84. You will monitor traffic on the through/right turn lane of this approach.

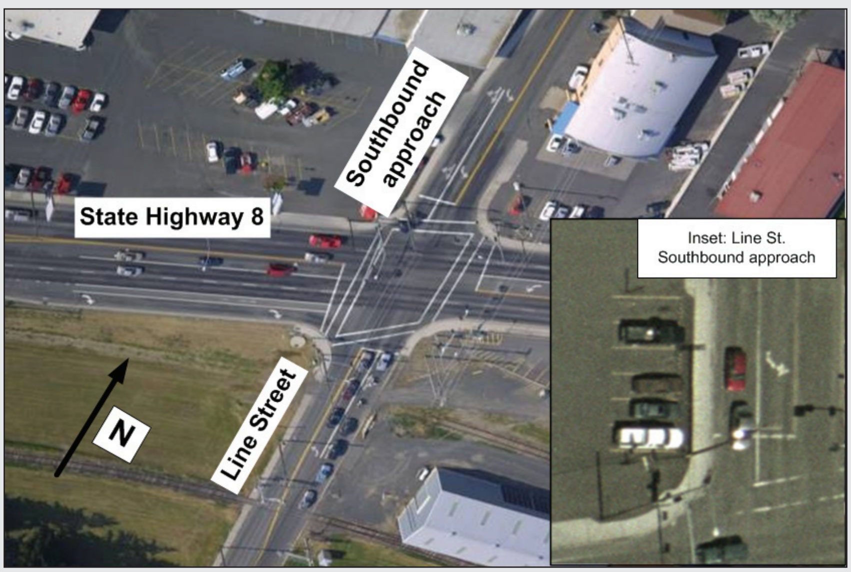


Figure 84. Aerial photograph of State Highway 8 and Line Street

In this activity, you will consider two cases, each illustrating a different method for the termination of phase 4 (which serves the SB through/right turn movements). You will observe how the phase times (the timing processes for the minimum green, vehicle extension, and maximum green timers), and how it terminates for each case. The two cases have been placed side-by-side in a movie format so that you can observe the traffic flow and timing processes at the same time. The simulation has been set to run at less than real time, slow enough so that you can observe all timing and traffic flow processes.

Task 1

Open the movie file: “A20.wmv.” Pause for a moment when you’ve opened the movie file. Look at the screen and see what you can observe. Note that there are always four kinds of information:

- The traffic flow conditions
- The status of the detectors (active or off)
- The status of the controller and the various timing processes
- The status of the signal display (red, yellow, and green)

Make a list of the various items that you see in this screen. Why do we record the observations that you make? One of the most important skills that we want you to develop is to learn to observe and make judgments about how well (or not) traffic is flowing based on what you observe about the traffic flow, the detector status, the controller processes, and the signal display.

Task 2

Observe the status at the beginning of phase 4 green. Move the animation to $t = 45.6$ seconds (which is equivalent to about 00:23 on the Windows Media Player clock). See Figure 85. Observe the following conditions for the scene on the left for the southbound approach.

- Two vehicles in queue, one of which is in the detection zone
- The red indication showing for the southbound movement (which is about to end)
- The ASC/3 controller status screen showing that phase 4 is just about to begin timing (“T”) and has an active call (“C”) from the detector
- The ASC/3 controller status screen showing that phase 4 is active in ring 1, that the minimum green timer is at 5.0 seconds, and that the maximum green timer is not active (“0.0”)

Note: There is a slight time delay between the ASC/3 controller and VISSIM, the simulation model. While the controller is now timing minimum green, the simulation will not be updated for a fraction of a second. As soon as you move forward from this instant in time, the simulation will show a green indication. These brief differences between what the controller is doing and what the simulation is displaying will only occasionally be noticeable (as when the simulation is paused).

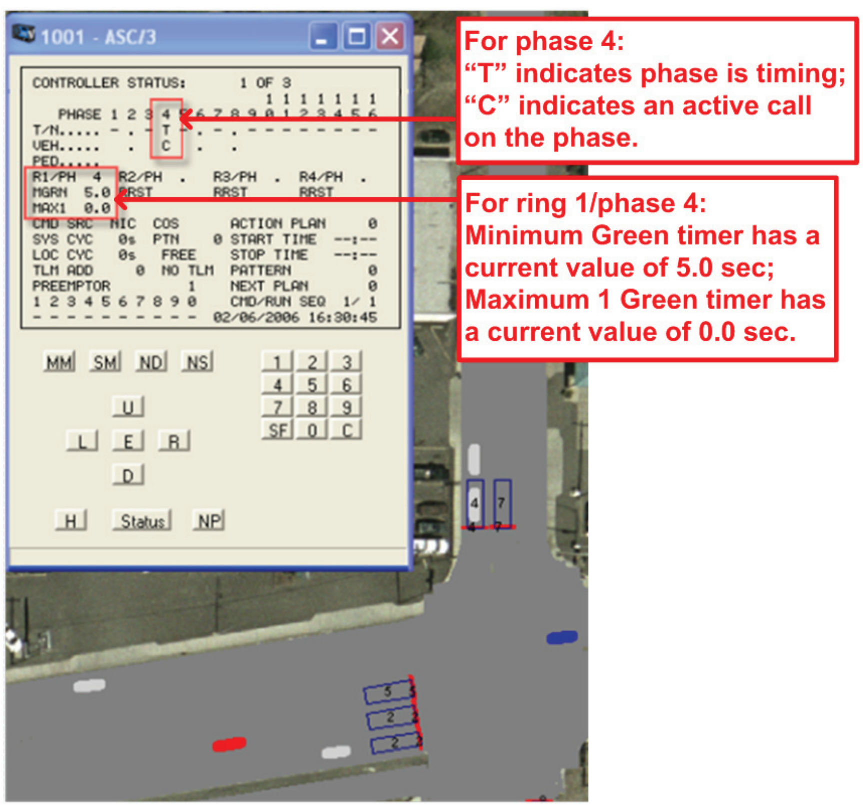


Figure 85. Traffic flow and controller status at $t = 45.6$

Task 3

Observe the two cases for one green indication. [Note: Remember, the animation that you are about to observe plays at much slower than real time. This will allow you to monitor the traffic flow and the timing processes at the same time!]

- Start the Windows Media Player animation
- First, watch the traffic flow, the detector status, and the timing processes for phase 4 for the case on the left. Monitor these conditions for the entire green indication
- When this green indication is nearly complete for the case on the left, consider the reason for the phase terminating
- Now turn your attention to the case on the right. The green indication is just beginning for this case. Again, monitor these conditions for the entire green indication.
- Note when the green indication ends for each of the two cases, and why

ACTIVITY

21 Exploring a Controller Emulator

DISCOVERY

Purpose

The purpose of this activity is to improve your understanding of the operation of an actuated traffic controller system by studying a traffic controller emulator.

Learning Objective

- Describe actuated traffic controller timing processes

Required Resource

- Spreadsheet file: A21.xlsm

Deliverable

- Prepare a document that includes a brief summary of what you've learned from studying the controller emulator, including answers to the Critical Thinking Questions

Information

You will use an Excel spreadsheet emulator to learn more about the operation of an actuated traffic signal controller. The spreadsheet (Figure 86) shows two intersecting one-way streets, a detector for each street, and the timers that are activated when a detector call has been initiated. The detection type is pulse, which means that the call is made and is not held after each actuation.

Critical Thinking Questions

1. How and when do the phases terminate when no detector calls have been placed?

2. When calls are placed continuously only on the NB approach, how and when does the northbound phase terminate?

3. When calls are placed continuously on both the northbound and westbound approaches, how and when does the northbound phase terminate?

4. How does pulse detection differ from presence detection and how does this difference affect the timing processes that you see in this controller emulator?

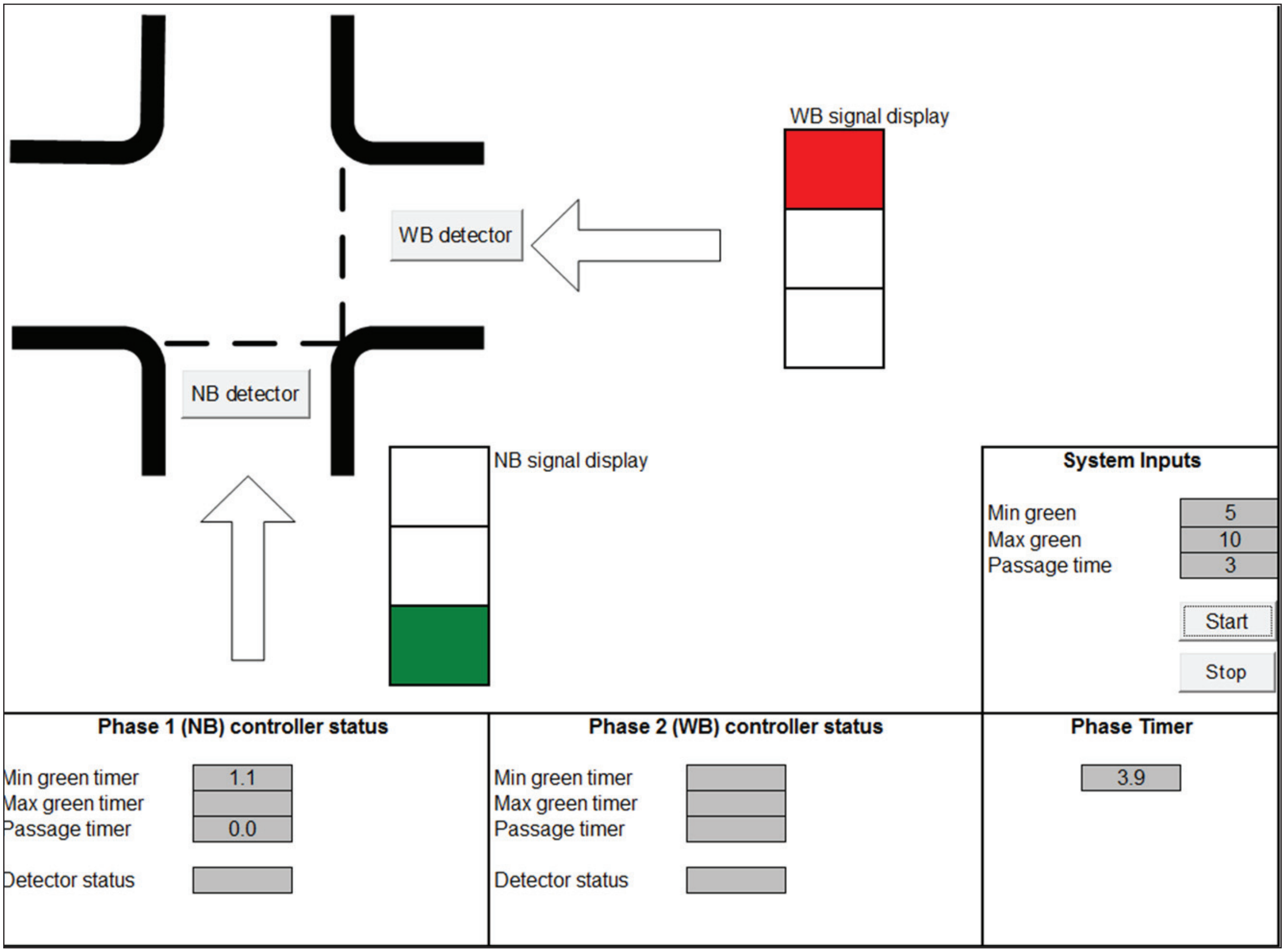


Figure 86. Spreadsheet controller emulator

Task 1

Run the Excel emulator without any detector calls. When and how do the phases terminate?

Task 2

Run the Excel emulator placing continuous calls only on the northbound approach. How long does the northbound phase run and why does it terminate?

Task 3

Run the Excel emulator placing continuous calls on both the northbound and westbound approaches. How long does the northbound phase run and how does it terminate?

ACTIVITY

22 Constructing a Traffic Control Process Diagram

DISCOVERY

Purpose

The purpose of this assignment is to help you improve your understanding of the operation of an actuated traffic controller system by studying eight cases of signal timing settings and preparing a traffic control process diagram for each case.

Learning Objective

- Describe actuated traffic controller timing processes

Deliverable

- Prepare a document that includes completed charts (Figure 87 through Figure 94), your answers to the Critical Thinking Questions, and a brief summary of what you have learned about the interrelationship between the detector and timing components of an actuated traffic controller.

Critical Thinking Questions

1. What questions do you still have on signal timing processes after completing this activity?

2. Can unused green time (the time after the last vehicle passes through the intersection and the onset of yellow) be effectively used? Describe some of the issues that you considered in your answer.

3. If you have to redraw any of the vehicle trajectories, how does this relate to the four interrelated steps in the traffic control process diagram that is first described in Chapter 1?

Information

traffic control process diagrams are presented for eight different cases. For each of these cases you are given the trajectories of one or more vehicles approaching and traveling through the intersection as well as the values for three timing parameters: the minimum green time, the passage time, and the maximum green time. For four of the cases, the detection zone for the active phase is six feet; for the other four cases, the length of the zone is 40 feet. One of the most important concepts in completing a traffic control process diagram is to note (as we first did in Chapter 1) the interrelationships of each of the components:

- The user is detected
- The detector sends this information to the controller
- The controller (through timing processes and control logic) determines the appropriate display
- The user responds to the display

Tasks

Notes:

(1) You may have to redraw the vehicle trajectories in response to changes in the display status.

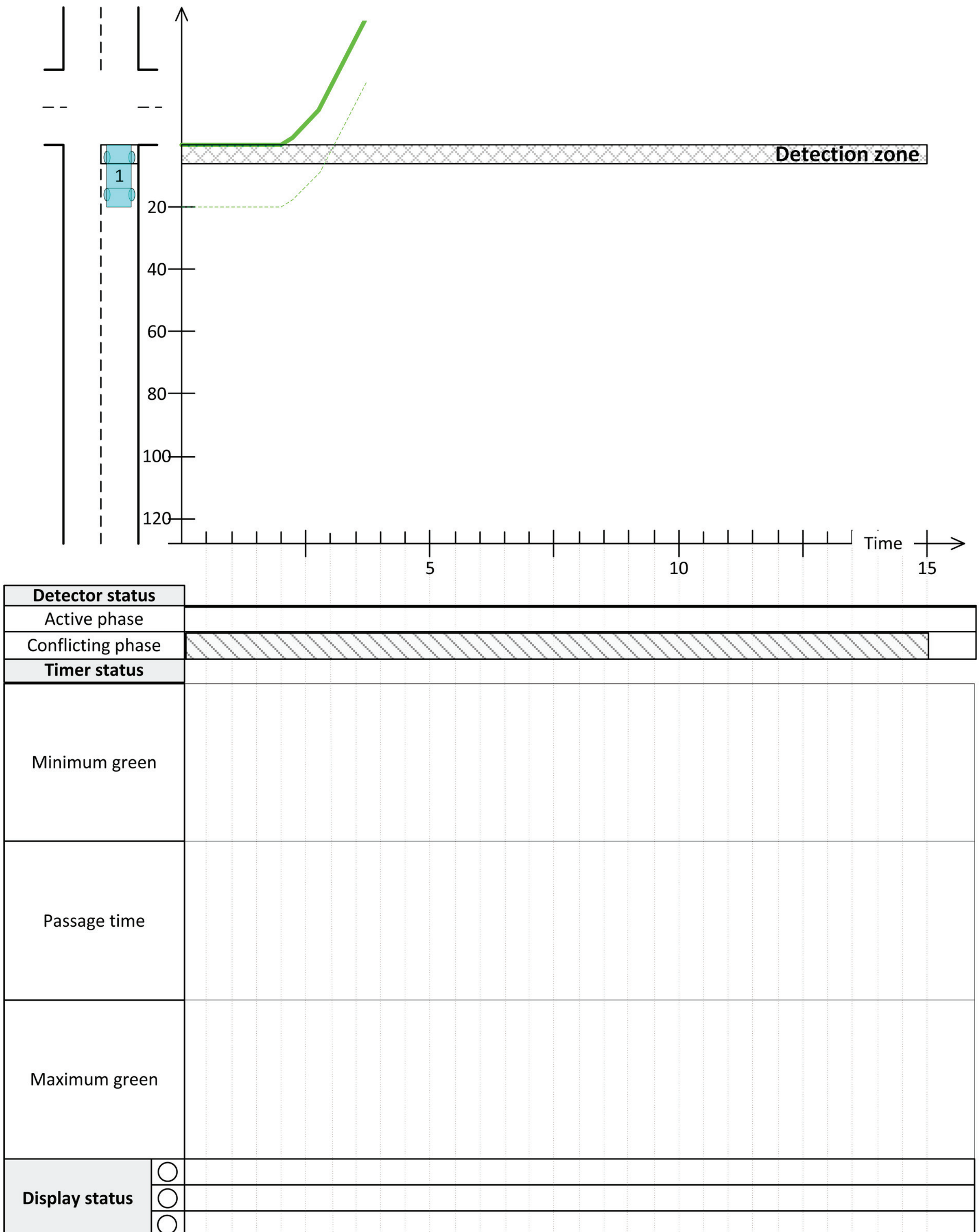
(2) The status of the detector for a conflicting phase is given: there is an active call on a conflicting phase when the area is hatched; there is no active call when the area is blank.

Task 1

Complete the detector responses, timer responses, and signal display responses for each of the eight cases that follow. The conditions for each case are shown in the lower right of each figure. Assume that the green time begins at $t = 3$ and that yellow time = 3 seconds and red clearance time = 1 second.

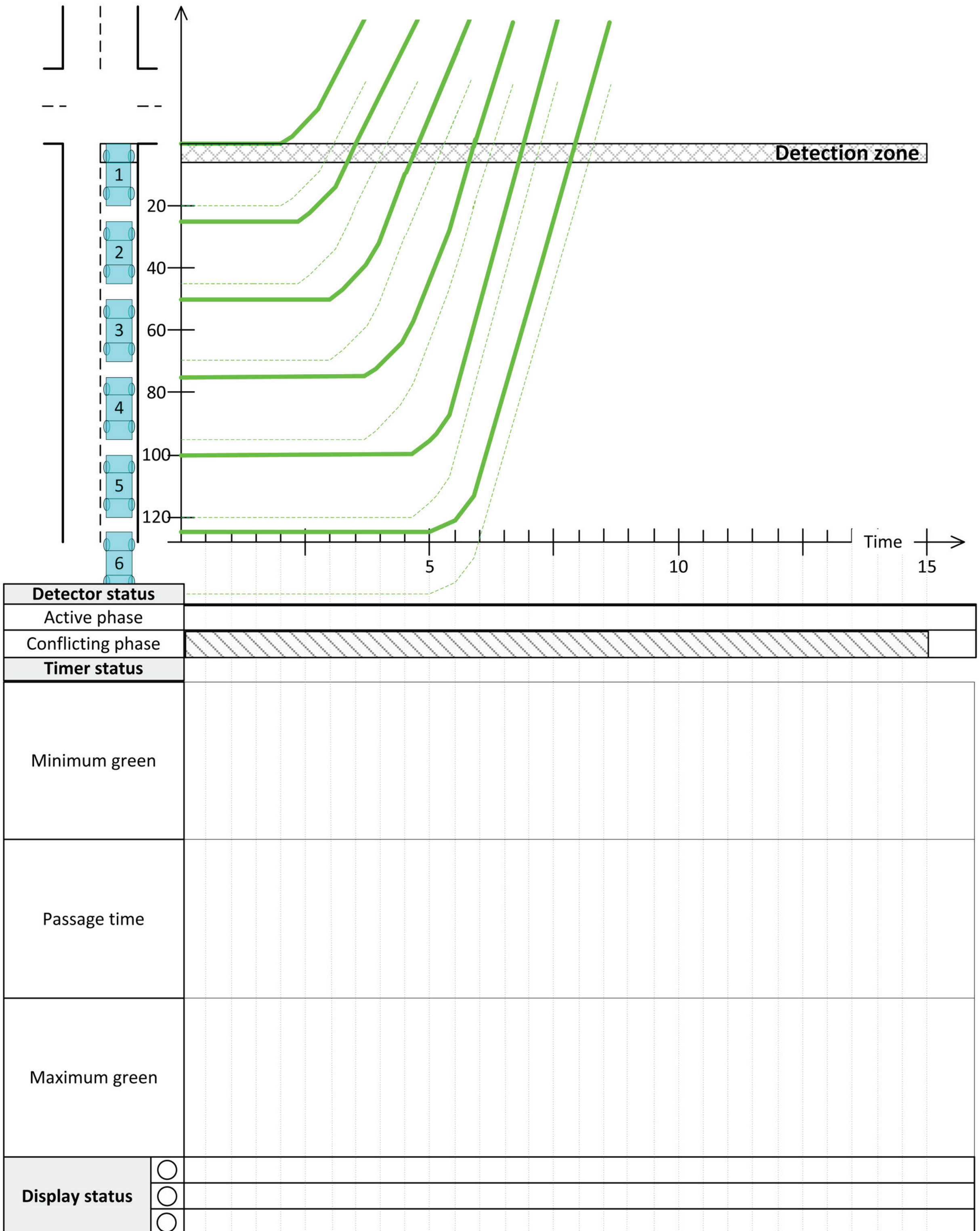
Task 2

Record the unused green time and the percentage of vehicles that are served for each of the eight cases.



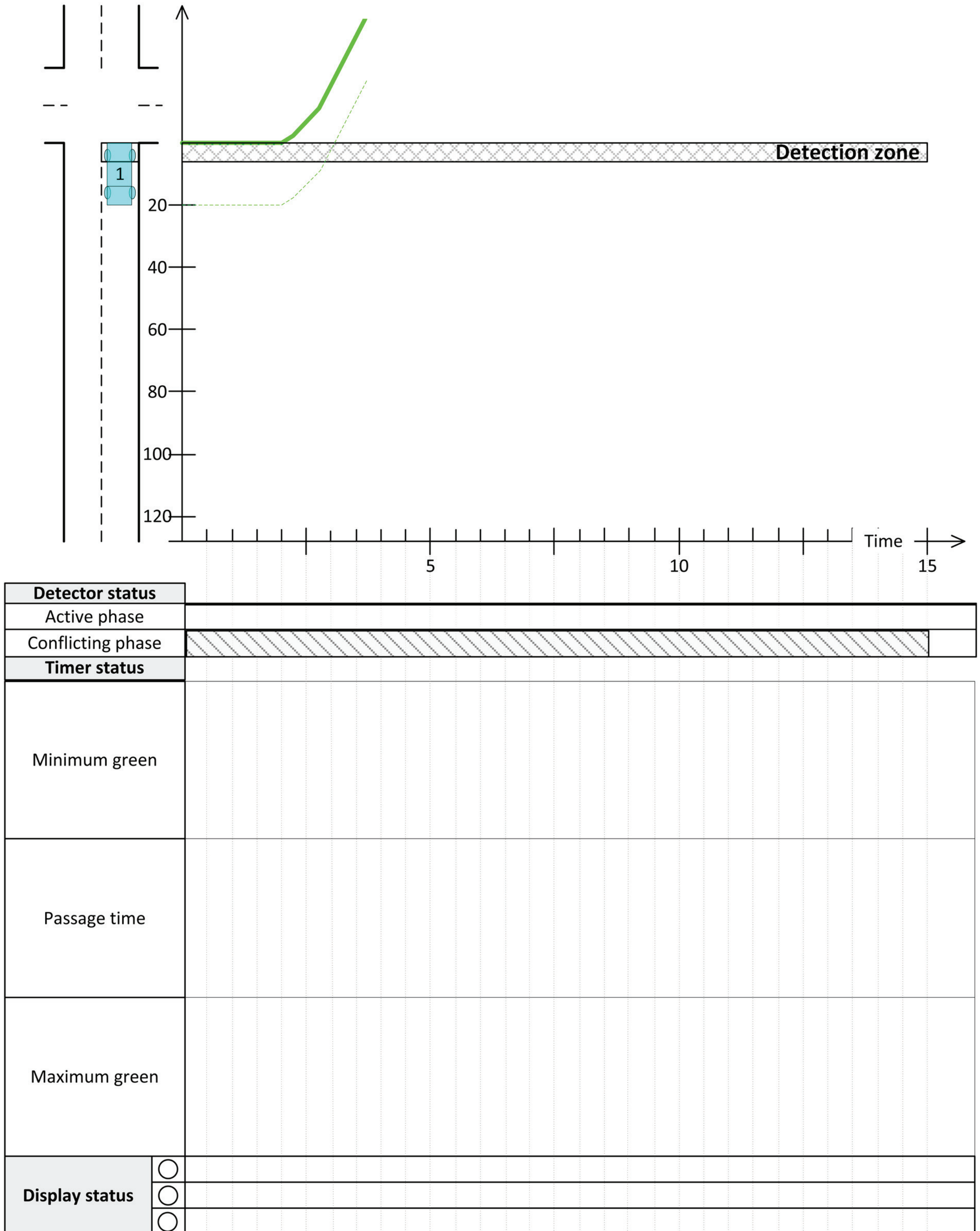
Min green	0s
Passage time	0s
Max green	15s

Figure 87. Traffic control process diagram - Case 1



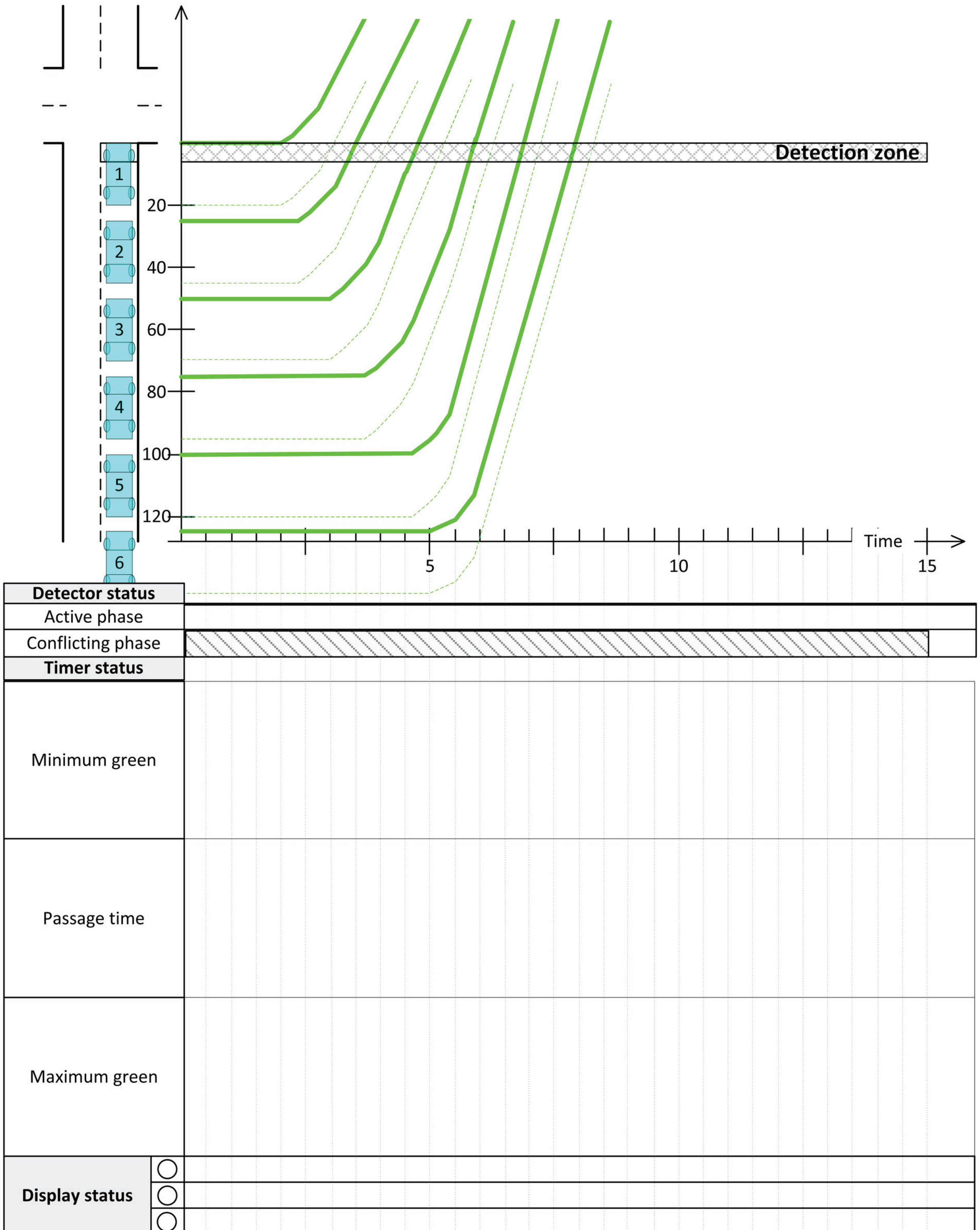
Min green	0s
Passage time	0s
Max green	15s

Figure 88. Traffic control process diagram - Case 2



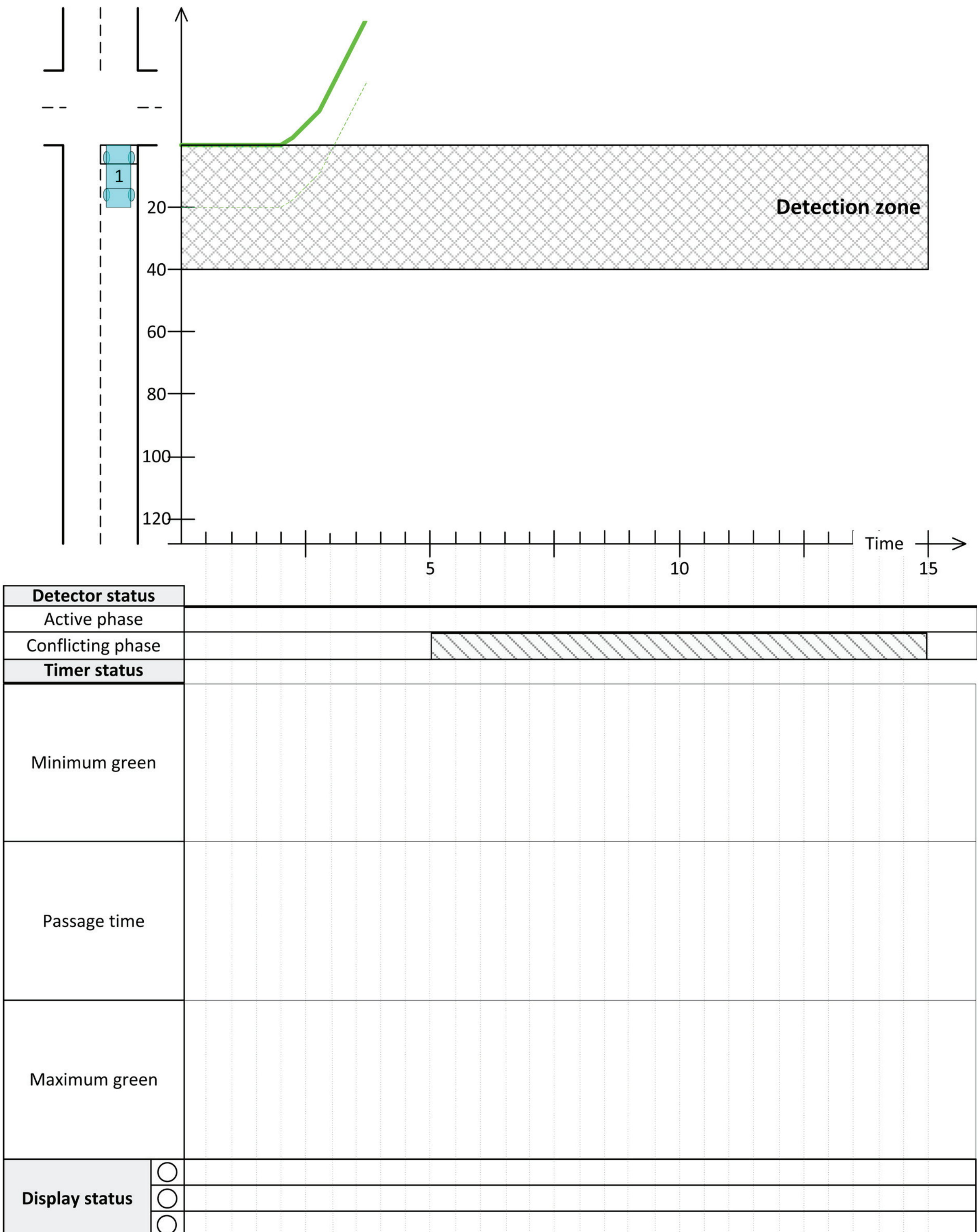
Min green	10s
Passage time	3s
Max green	15s

Figure 89. Traffic control process diagram - Case 3



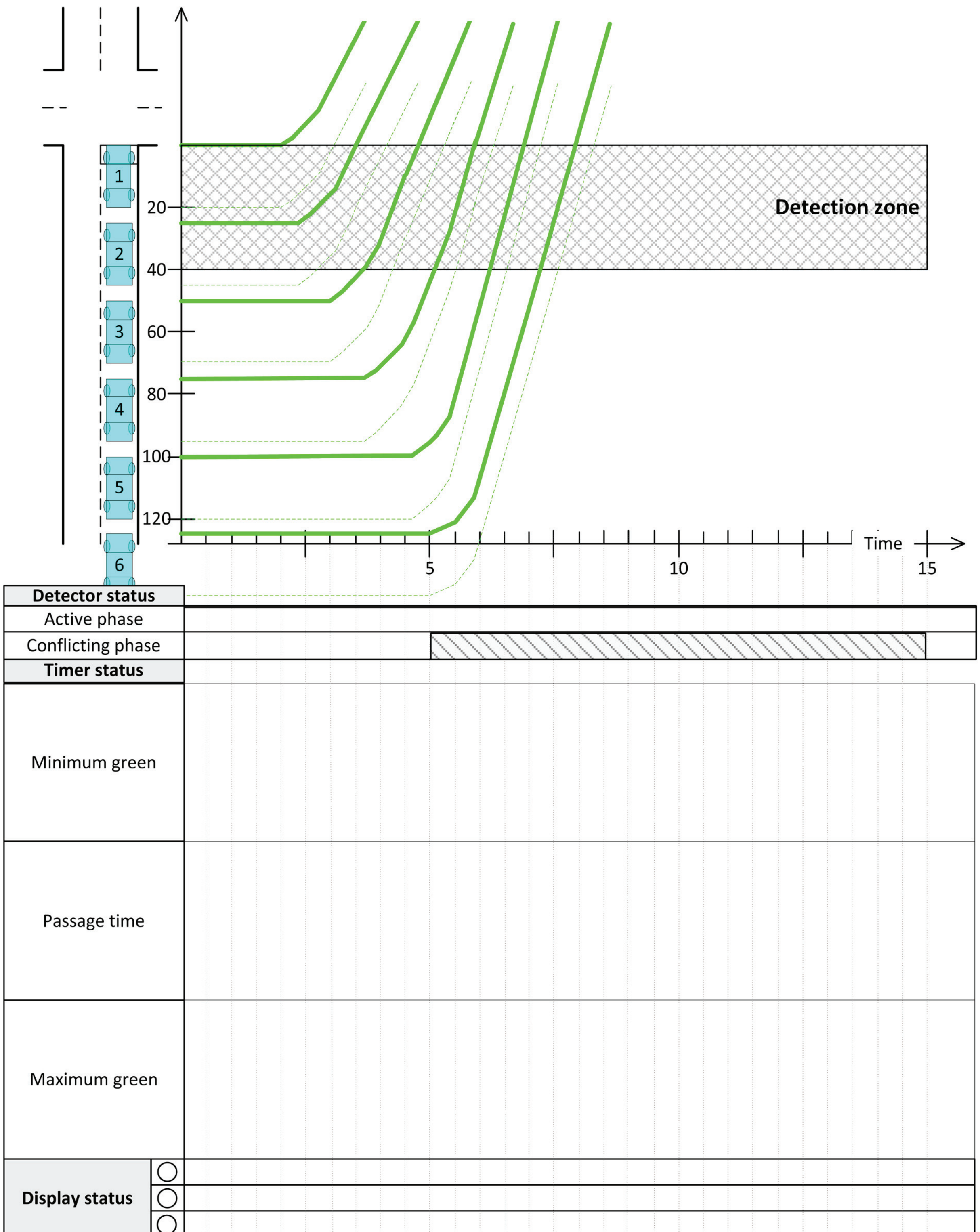
Min green	10s
Passage time	3s
Max green	15s

Figure 90. Traffic control process diagram - Case 4



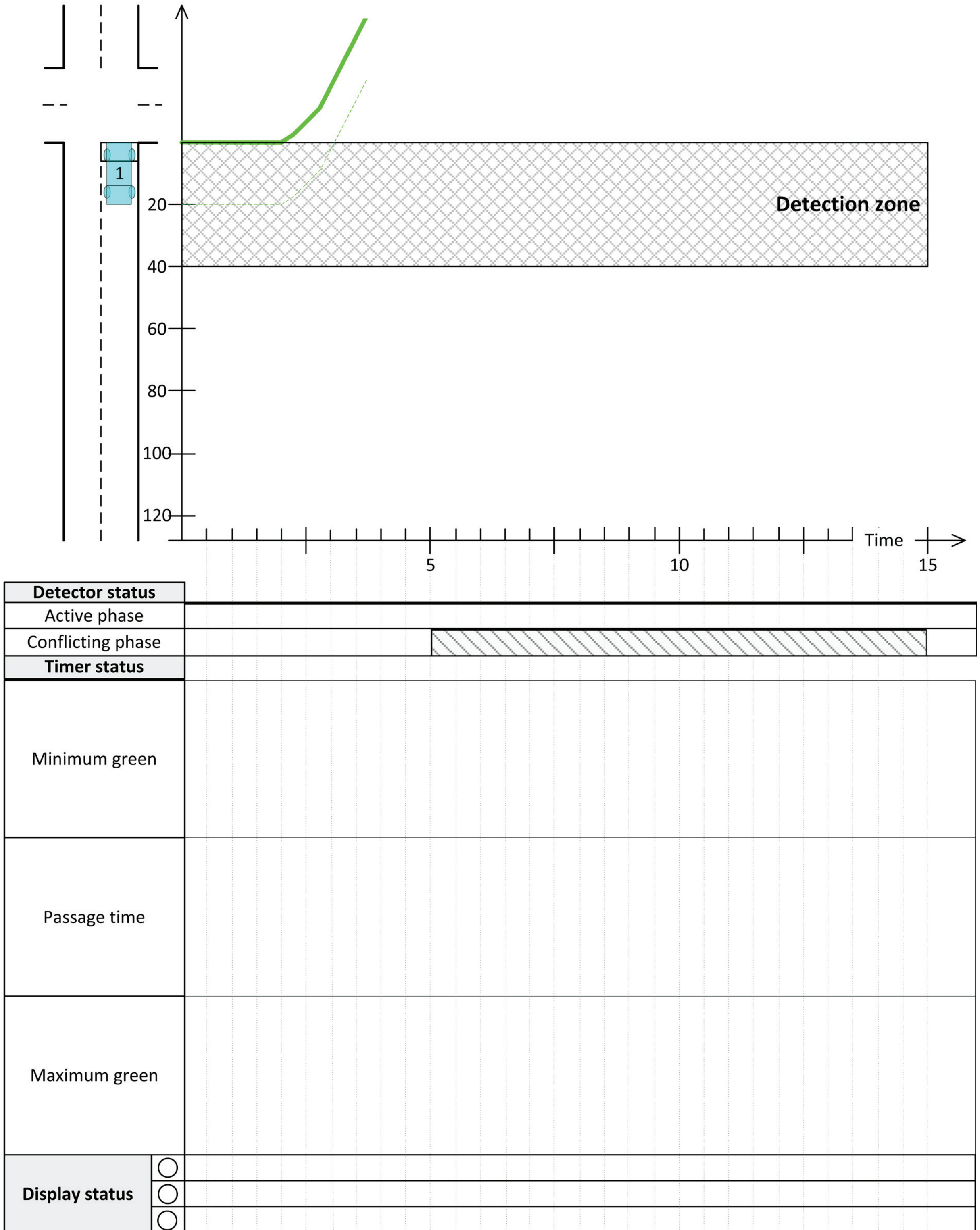
Min green	0s
Passage time	0s
Max green	15s

Figure 91. Traffic control process diagram - Case 5



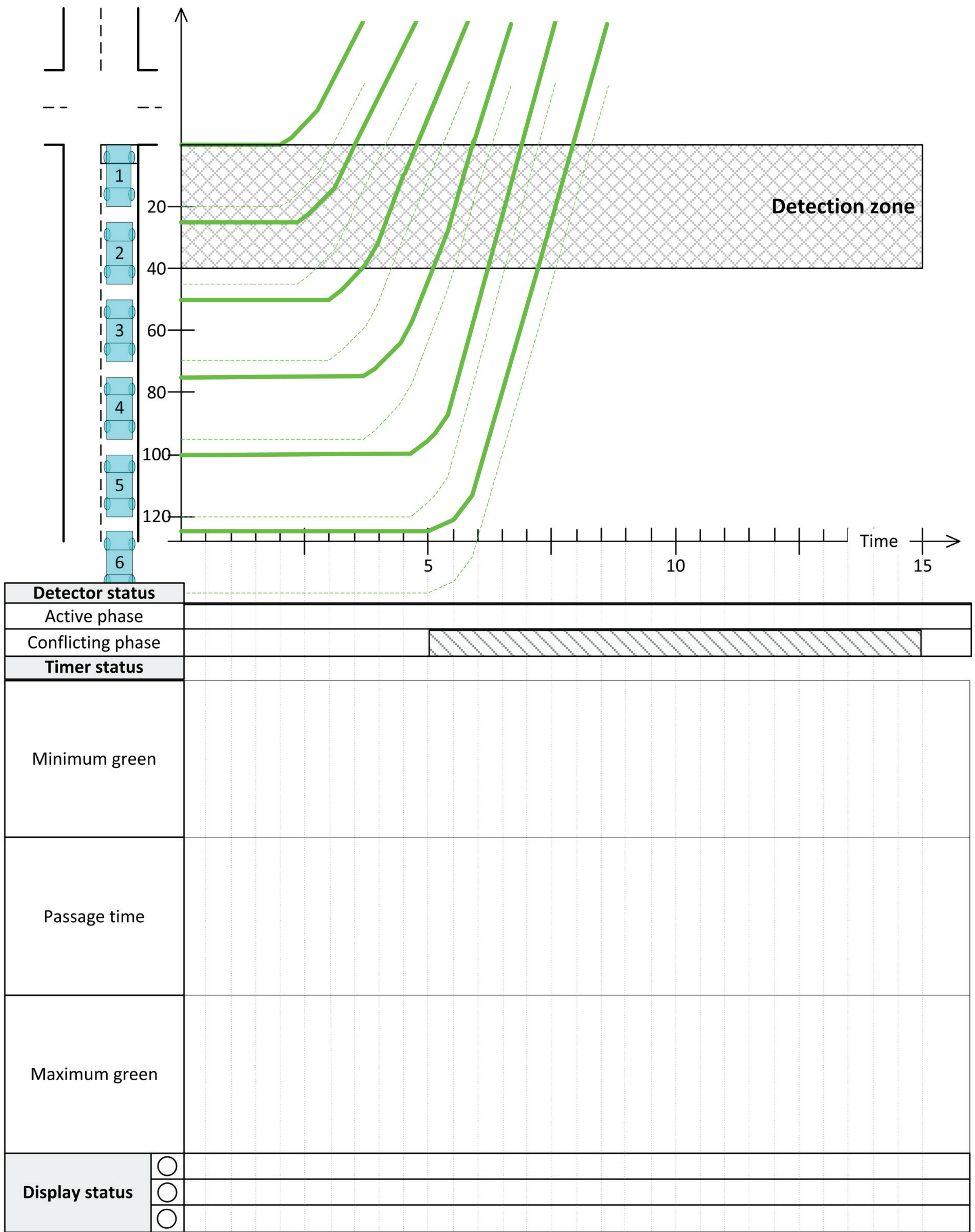
Min green	0s
Passage time	0s
Max green	15s

Figure 92. Traffic control process diagram - Case 6



Min green	10s
Passage time	3s
Max green	15s

Figure 93. Traffic control process diagram - Case 7



Min green	10s
Passage time	3s
Max green	15s

Figure 94. Traffic control process diagram - Case 8

ACTIVITY

23 Inferring Signal Timing Parameter Values

FIELD

Purpose

The purpose of this activity is to test your understanding of traffic controller operations by inferring the value of the three standard signal timing parameters by observing traffic flow and signal displays in the field.

Learning Objective

- Infer signal timing parameter values through field observations

Deliverable

- Prepare completed charts with data as required for the following tasks, including inferred values of the signal timing parameters

Information

You will make field observations for one approach of the same intersection that you studied in Activity #15 (in Chapter 3) and for which you constructed a ring barrier diagram. You will record the detector status data and the signal display data for one approach of that intersection using forms shown in Table 10a and Table 10b. A major challenge of this activity is to infer the values of the timing parameters solely through observation of the vehicle arrival patterns and the signal displays on the approach that you are observing.

As you are collecting your data, look for traffic conditions that would allow you to observe the minimum green time, such as a queue of just one vehicle. Also, note that pedestrian calls may affect your timing observations, so it is best to not collect data when there is a pedestrian call.

Critical Thinking Questions

1. One complicating factor in the determination of your timing values is the interaction of your approach with the opposing approach. Describe how this interaction may affect the conclusions that you make about the timing values that have been set for your approach for the vehicle extension time.

2. Why is the maximum green time difficult to determine if the volumes on your approach are low?

3. What changes would you make in the way in which you made your observations and collected your data to improve the precision of your estimates?

Task 1

Document the location of the detector or detectors on one approach of your intersection.

Task 2

For a period of 15 minutes, record the following data for this approach:

- The times that each detector changes its state (from on to off, and from off to on) based on your knowledge of where the detection zone is placed on the approach
- The times that the signal display changes its state (when green starts, yellow starts, and red starts)

Task 3

Prepare traffic control process diagram sketches (see Figure 95) for enough cycles for which you've collected data to show how you've inferred the signal timing data, noting the detector status as well as the signal display status data. Based on these sketches, estimate the values for the minimum green time, the passage time, the maximum green time, the yellow time, and the red clearance time.

Table 10a. Detector state data collection form

Time	Detector state (on/off)

Table 10b. Display state data collection form

Time	Display/color indication

Detector status	
Active phase	
Conflicting phase	
Timer status	
Minimum green	
Passage time	
Maximum green	
Display status	

Time →

Figure 95. Traffic control process diagram for field data observations

ACTIVITY

24 Signal Timing Parameters

IN PRACTICE

Purpose

The purpose of this activity is to give you the opportunity to learn how the *Traffic Signal Timing Manual* describes some of the signal timing parameters that you studied in this chapter.

Learning Objective

- Contrast the description of the signal timing terms that are presented in this chapter with those described in the *Traffic Signal Timing Manual*

Required Resource

- *Traffic Signal Timing Manual*

Deliverables

Prepare a document that includes

- Answer to the Critical Thinking Question
- Completed Concept Map

Link to Practice

Read the sections of the *Traffic Signal Timing Manual* assigned by your instructor.

Critical Thinking Question

When you have completed the reading, prepare an answer to the following question:

1. Describe how the timing processes that you observed in the field (Activity #23) compare with their descriptions in the *Traffic Signal Timing Manual*.

In My Practice...

by Tom Urbanik

Stop bar detection can be very efficient in allocating green time if the detection zone is large and the passage time is small (zero or close to zero). If the passage time is zero, the approach turns yellow as the vehicle leaves the stop bar. However, the onset of yellow occurs when the vehicle is well into the intersection. To achieve an even more efficient operation (and also provide dilemma zone protection which is not discussed here), separate setback (from the stop bar) detection is used.

The design of setback detection is complex. However, to illustrate the point, consider a detector located 3 seconds from the stop bar. If the gap time is 2 seconds, the vehicle is approximately 1 second from the stop bar if it is the last vehicle to gap out. At 1 second from the stop bar, there is no question that the vehicle will enter the intersection as it will take 1 second to react to the yellow. This type of operation is safer and more efficient.

CONCEPT MAP

Terms and variables that should appear in your map are listed below.

gap out	maximum green	passage time
max out	minimum green	

Student Notes: