ACTIVITY 1

# Exploring the System and Proving a Framework

READING

## Purpose

The purpose of this activity is to help you develop a base knowledge of the introductory concepts relating to traffic control systems.

## Learning Objective

- Describe basic components and operations of the traffic control system

## 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 and variables. Paraphrasing a formal definition (as provided by your text, instructor, or another resource) demonstrates that you understand the meaning of the term or phrase.

| | |
|---|---|
| **actuated control** | |
| **detector** | |
| **display** | |
| **fixed time control** | |
| **movement** | |
| **queue** | |
| **user** | |

## Critical Thinking Questions

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

1. In contrast to fixed time control, in what situations is actuated control appropriate?

2. Describe the interrelationships that are shown in Figure 5 and Figure 6 between the components of the traffic control system.

3. How would you measure the performance of the traffic control system and what data would you need to make these measurements?

4. What are the primary physical elements of a signalized intersection?

5. What are the discrete periods of traffic flow during one signal cycle? Briefly describe the manner in which vehicles arrive and depart during each of these periods.

6. List any other questions that you have on the reading material.

## Information

**The Traffic Signal Control System and Its Components**

The primary purpose of a traffic signal control system is safety, to avoid conflicts by providing a time-separation between the movements of people and vehicles traveling through the intersection. An important, but secondary purpose of the system is to provide priority to certain groups or users to achieve goals or objectives that have been established for the performance of the system.

Often the transportation engineer addresses a traffic problem for one or more arterials, with each arterial consisting of a number of individual intersections that are controlled by traffic signals. Many arterials are designed to move large numbers of users, including auto drivers, transit riders, bicyclists, and pedestrians, through the system with as few stops as possible. These coordinated systems often give priority to certain users (for example, transit riders) based on the performance objectives or desired outcomes that have been set for the system. Figure 2 shows a view of a street in downtown Portland, Oregon, that operates under a coordinated system.

**Figure 2.** Aerial view of a street in Portland, Oregon

At other times, the focus of the transportation engineer is the operation of an individual intersection. Figure 3 shows a signalized intersection serving three user groups: vehicles and bicyclists traveling through the intersection and pedestrians crossing the street.

Intersection traffic control can either be fixed time or actuated (see Figure 4). In fixed time or pretimed systems, the green interval and cycle length are fixed and do not vary even as traffic demand varies though there may be plans for different periods of the day. Actuated control systems respond to traffic demand by extending the green interval by a specified amount of time each time a new vehicle arrives on an approach. The green interval will last at least a minimum specified time but no longer than a pre-established maximum time. More advanced control strategies are based on adapting timing plans to changing traffic patterns during the day.

**Figure 3.** Intersection in Portland, Oregon

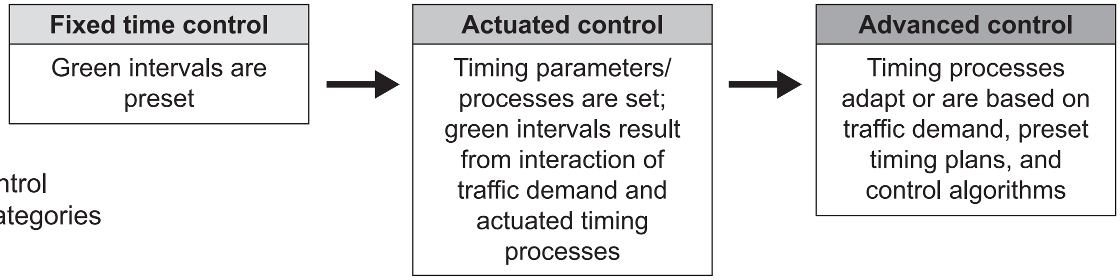


**Figure 4.** Traffic control system categories

The focus of this book is on the operation and design of a single intersection, operating under actuated control, serving only vehicles (or people driving passenger cars and trucks). The primary benefit of this approach is that it allows you to learn about the basic components of the operation of an actuated control system, without the complexity of considering more advanced control strategies and the needs of other users (such as transit riders or pedestrians). This focus may be criticized because of the importance of considering all modes or users, and the growing interest in providing priority to non-automobile modes at a signalized intersection. However, we believe that the benefits to you in learning the fundamentals of signal timing and operations in this context (single intersection, vehicle user) will allow you to take the next steps of considering the more complex issues of pedestrian timing, transit priority, signal coordination, and others, using the knowledge and skills gained from this book as a solid foundation. So the operating environment that you will address is a single intersection with vehicle drivers as the user class.

One way to view an actuated traffic control system is to consider the components shown in Figure 5. The inputs to the system are the level of vehicle demand and the physical geometry or layout of the intersection. The traffic control system itself is composed of four components: the users of the system, detectors or sensors, the traffic controller, and the display. These components work together in pairs, in a linear fashion, as shown in Figure 5. Each component is connected directly with two of the other subsystems, dependent on or responsive to one and directly influencing the other. These four components are, of course, affected by the geometry of the intersection itself and the volume of the users that demand service at the intersection. Sometimes signal timing can't completely address a performance problem and the only practical solution may be a change in the intersection geometry, as shown in the bottom feedback loop in Figure 5. The change in geometry could be an increase in the number of lanes.

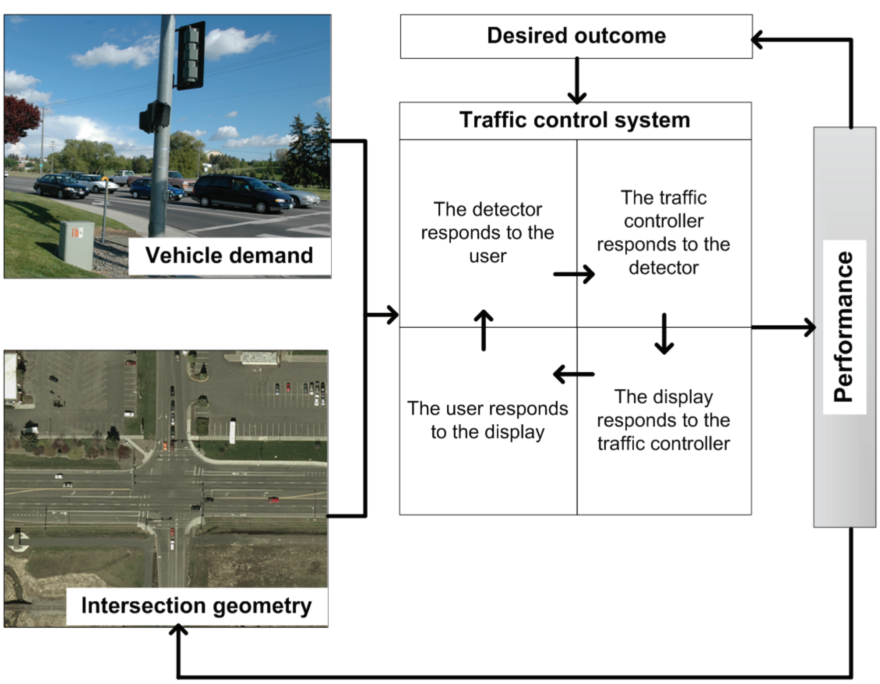


**Figure 5.** Traffic demand, geometry, control system, and performance

While we as engineers may be most interested in the design of the intersection itself, most people who travel through the intersection are not. They are interested in traveling through the intersection without stopping, and if they have to stop, they don't want to have to stop for long. An important part of the design process is to establish the desired outcome, or what do we want to accomplish with our design. For example, one objective could be to minimize the delay for all users, and this objective could be accomplished by limiting the maximum amount of green time that is given to each user. We can determine how well we meet the desired outcome by establishing performance measures. We measure the performance of the intersection, from the perspective of the users, based on how often people or vehicles must stop when traveling through the intersection, how long they stop, and the length of queues that form when they do stop. We define these measures as number of stops, delay, and queue length. These measures form the basis for evaluating how well the intersection performs.

Figure 6 shows an expanded view of the traffic control system and its components. Each of these components (the users, the detectors or sensors, the traffic controller, and the display) will now be discussed in greater detail.

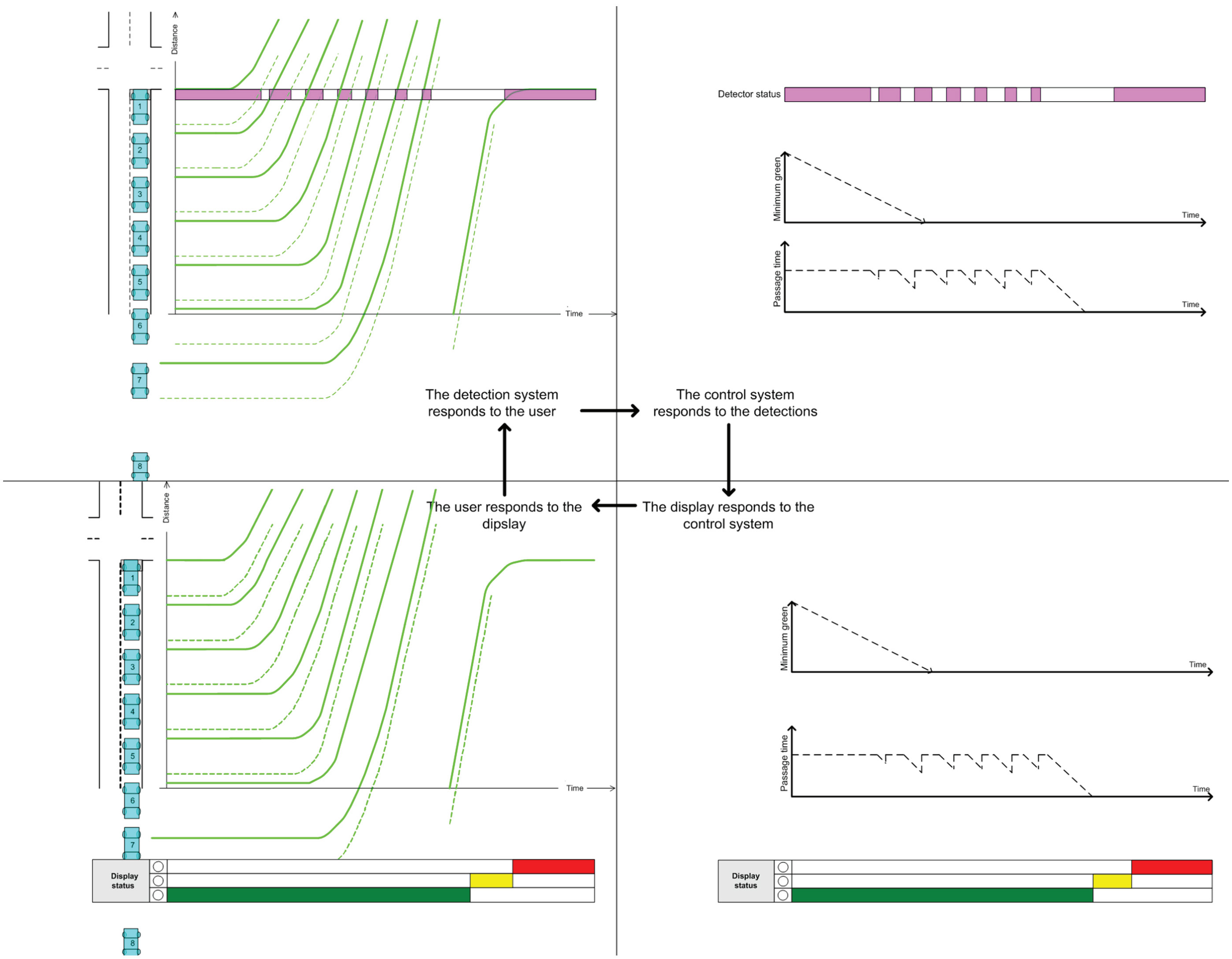


**Figure 6.** The traffic control system and its components

### *Users*

A vehicle user can include the driver of a passenger car, a truck, or other commercial vehicle that desires service at (desires to travel through) the intersection. Each user category has a set of attributes such as length, width, acceleration and deceleration capabilities, and capacity that affect the operation of the intersection and its required signal timing. Users respond to the display with various possible actions, depending on the display state, the distance that the user is upstream of the intersection stop bar, the speed that the user is traveling, and other factors.

Figure 7 shows a time-space diagram that illustrates how users respond to the display. The figure shows the trajectories for the front and rear of eight vehicles in the format of a time space diagram. The first seven vehicles are part of a queue that has formed during the red interval. The vehicles respond to the change in the display (from red to green), perceiving the change, responding to the change by accelerating and traveling through the intersection. The last vehicle (vehicle 8) responds to the change in the display from green to yellow by decelerating and stopping.

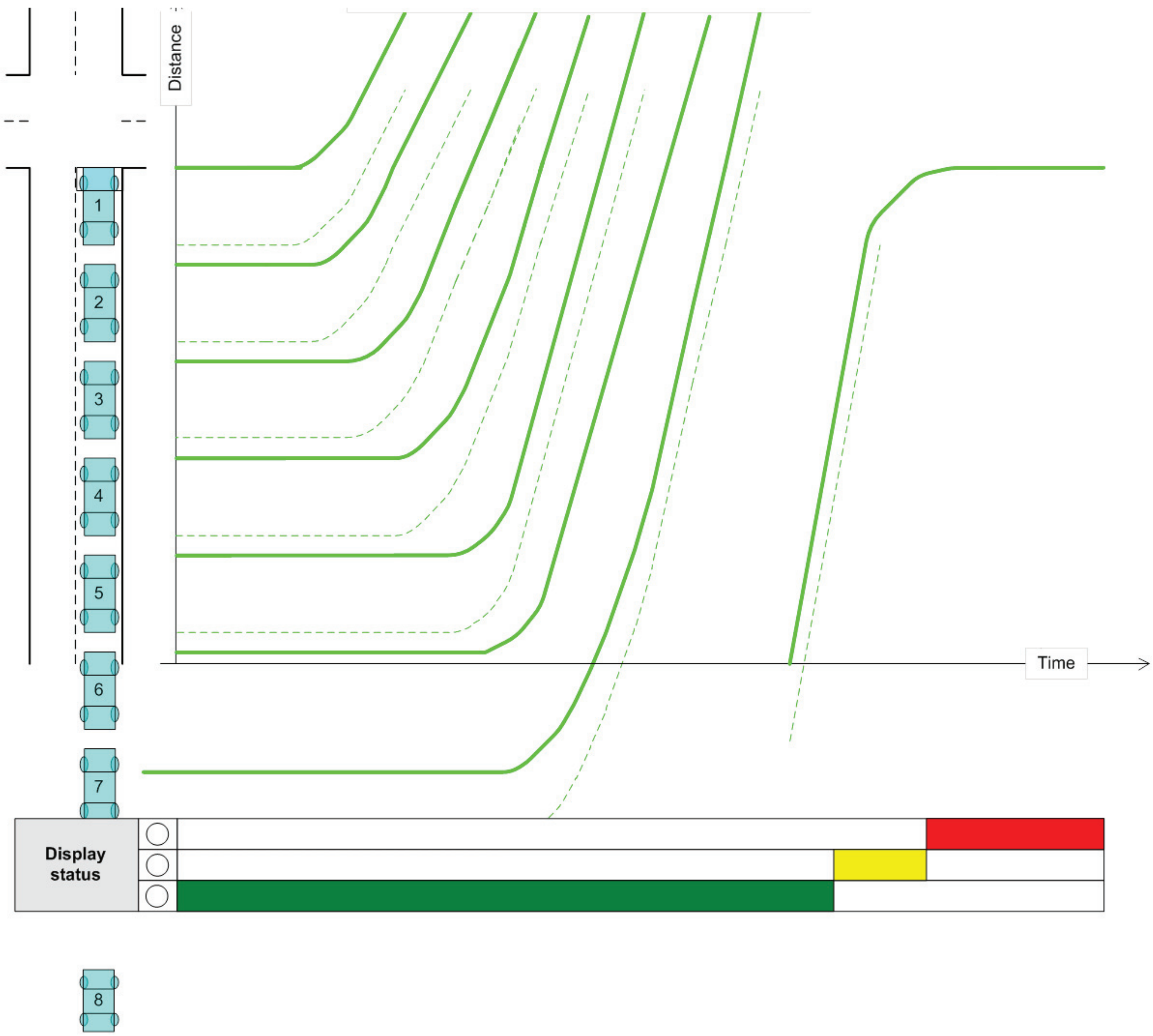


**Figure 7.** Users responding to the display

***Detectors***

There are a variety of detectors or sensors used at signalized intersections including inductive loops, video, microwave, and others. Inductive loops include pulse and presence detection types. We will focus on presence loop detectors that are "active" or send a "call" to the controller as long as a vehicle is within the detection zone.

Figure 8 shows the interaction between vehicles and the detector. The vehicle trajectories that we saw in the previous figure (showing both the front and back of each vehicle) are repeated here. The detection zone shown here is located at the intersection stop bar. We can follow the state of the detector over time. The presence of the vehicle in the detection zone is noted by the solid color. When no vehicle is present in the zone, the detector status is off and no color is shown.

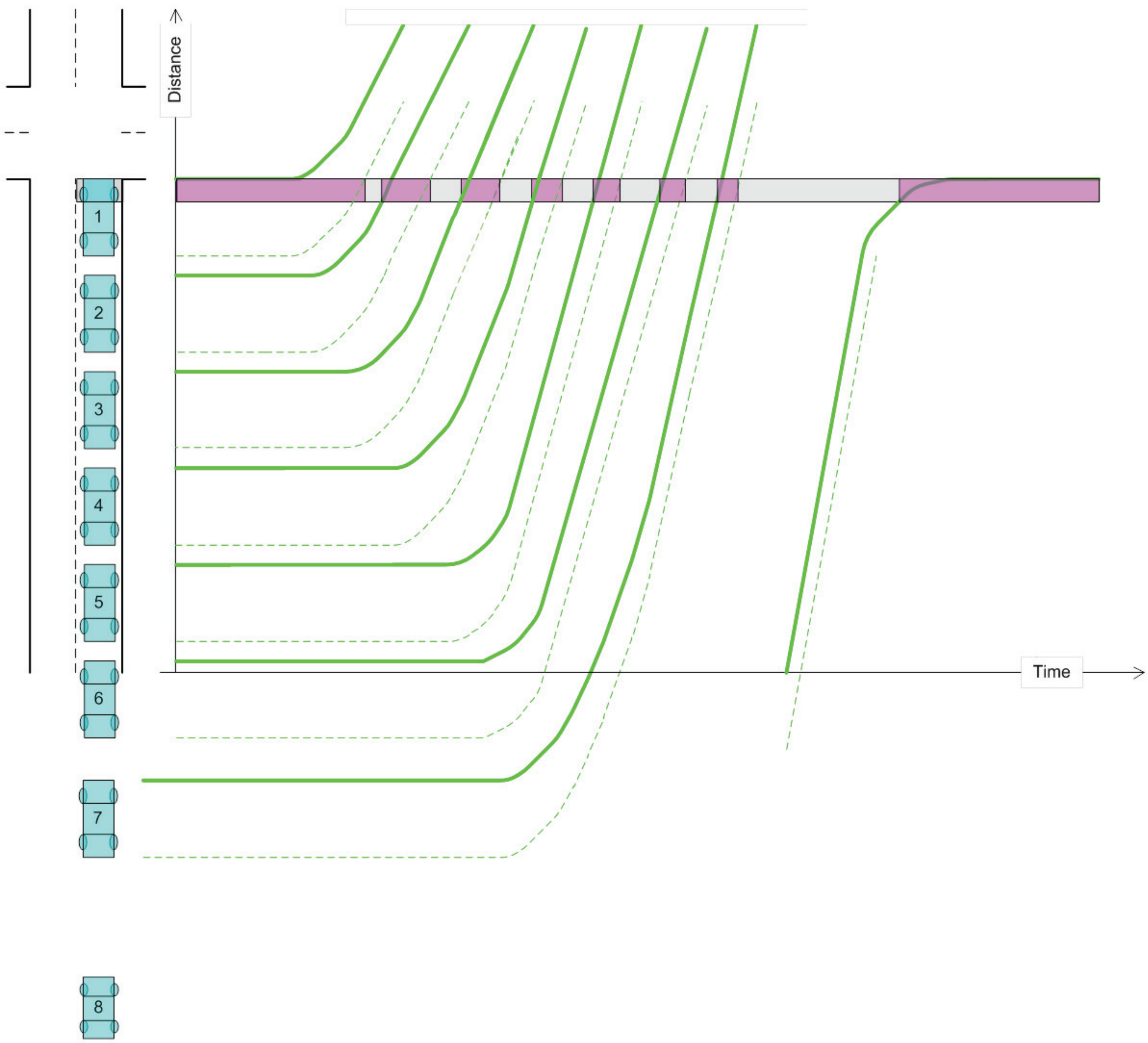


**Figure 8.** Detectors responding to users

***Controller***

The traffic controller receives calls or requests for service from the detectors. The controller determines which group of users (movements) are to be served at any given time (the order or sequence of service) and the duration that each group of users is served. The duration of service is determined by the status of a set of timing processes and a decision making framework that responds to this status to determine when service to a particular group of users will end. Examples of these timing processes are the minimum green time, the vehicle extension or passage time, and the maximum green time.

Figure 9 shows the response of two controller timing processes to the detector status. The first timing process, the minimum green timer, becomes active at the beginning of the green interval, and continues timing until the timer reaches zero and expires. In this case, there is no direct link between the detector and the timing process. The second timing process, the passage timer (sometimes called the *vehicle extension timer*), also begins timing at the beginning of the green interval but is continually reset as long as the detector is active (a vehicle is present in the detection zone). When the detection zone is not occupied, the passage timer begins to time down. The timer is reset six times in the example shown in the figure, each time representing when a vehicle enters the zone. The timer finally expires when the time that the zone is unoccupied exceeds the value of the passage time set in the controller. You will learn more about these timing processes in Chapter 4.

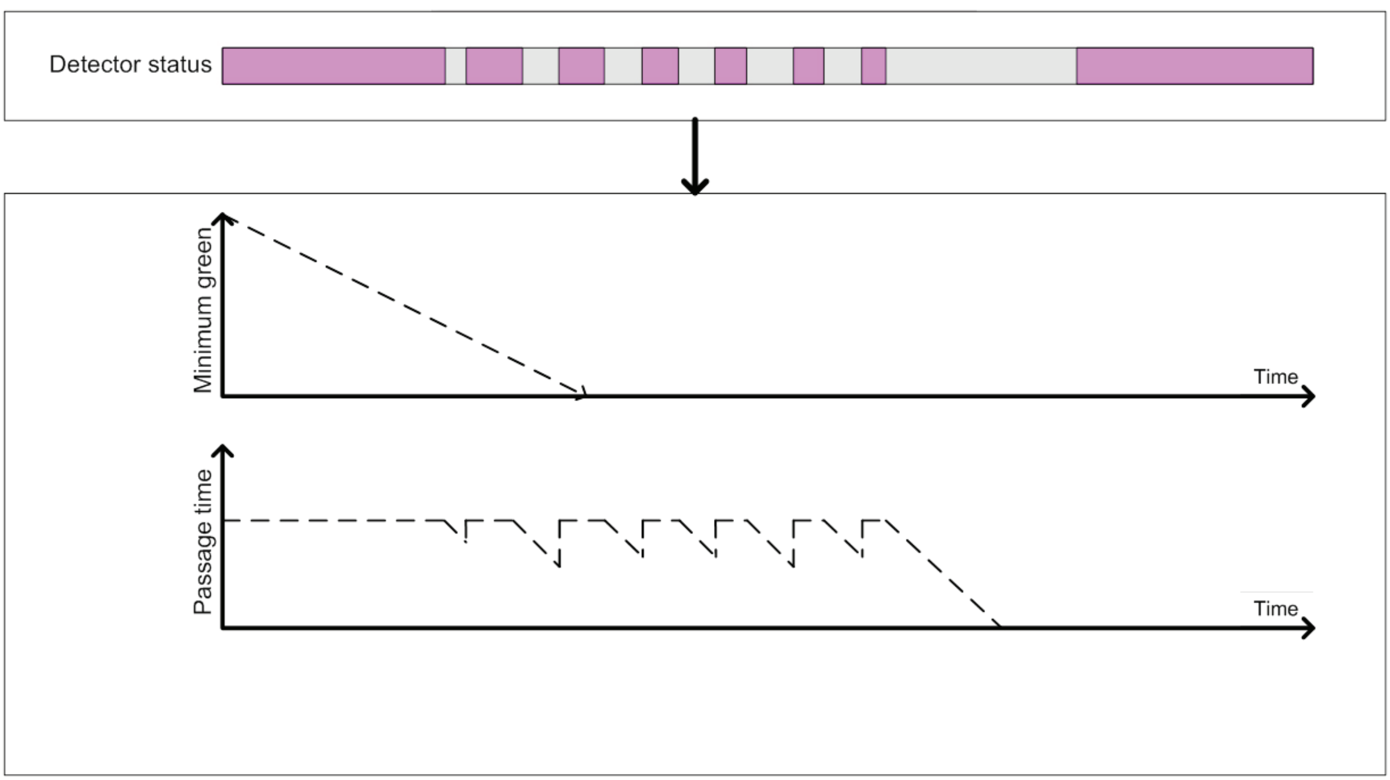


**Figure 9.** Controller responding to detector

### *Display*

The display is a set of indications that provide information to users on what to do as they approach or are stopped at the intersection. The information conveyed by an indication can either be to proceed through the intersection ("go"), to exercise judgment on whether to go or stop because a change in right of way is about to occur or that the intersection needs to be cleared, or to come to a stop. The state of an indication can either be active or off. If the state is active, it can be either steady or flashing. A color is associated with the vehicle display and can be either green, yellow, or red.

Figure 10 shows an example of the response of the display to the traffic controller. Here, the green is displayed as long as both the minimum green timer and the passage timer are active. In this example, when the passage timer expires, the display changes to yellow and then to red. You will learn about these and other timing processes and how their status affects the displays later in this book.

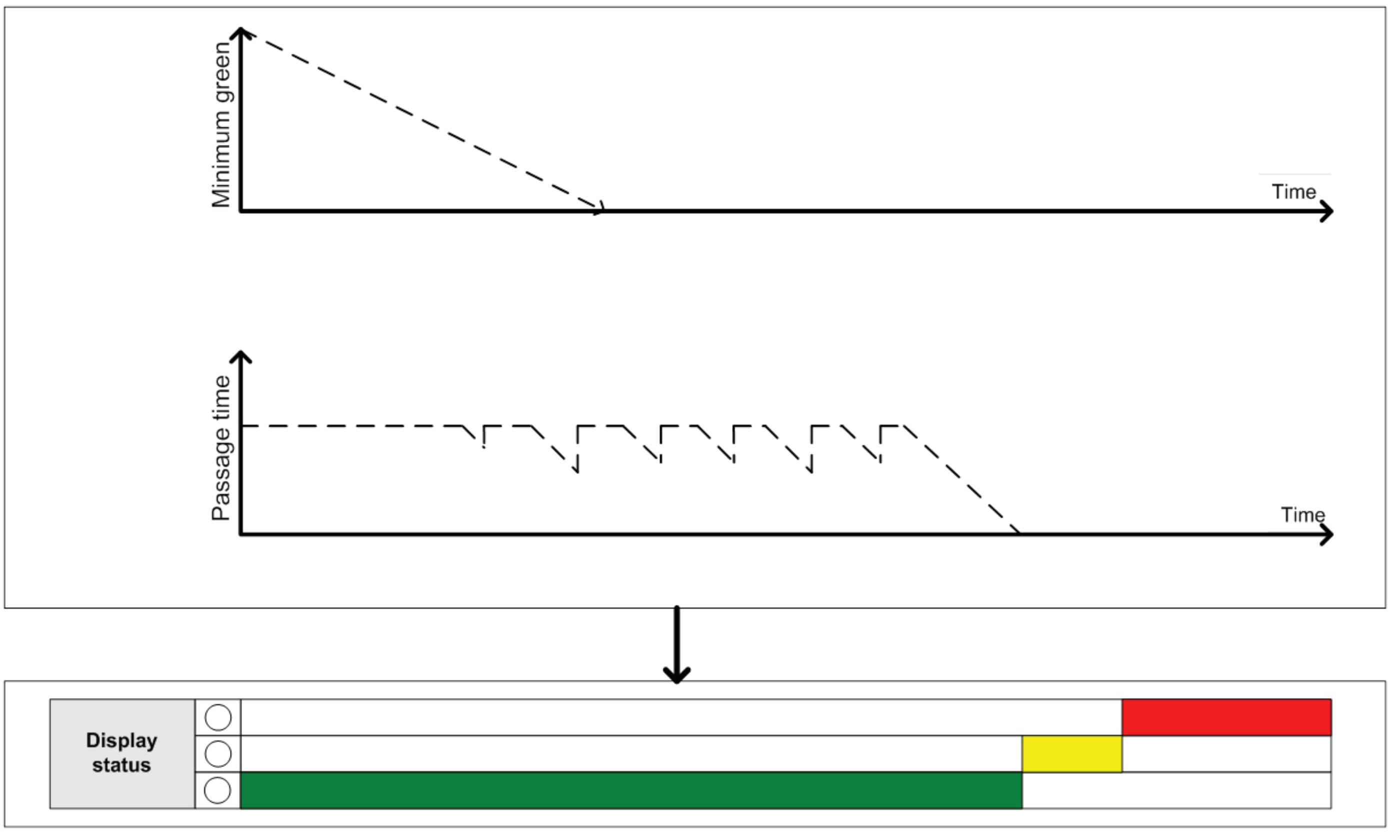


**Figure 10.** Display responding to the controller

We can also view these components together in one diagram, called a *traffic control process diagram*, as shown in Figure 11. You will use this diagram to follow the effects of a given traffic demand on the detectors, the traffic controller, and the display later in this book.

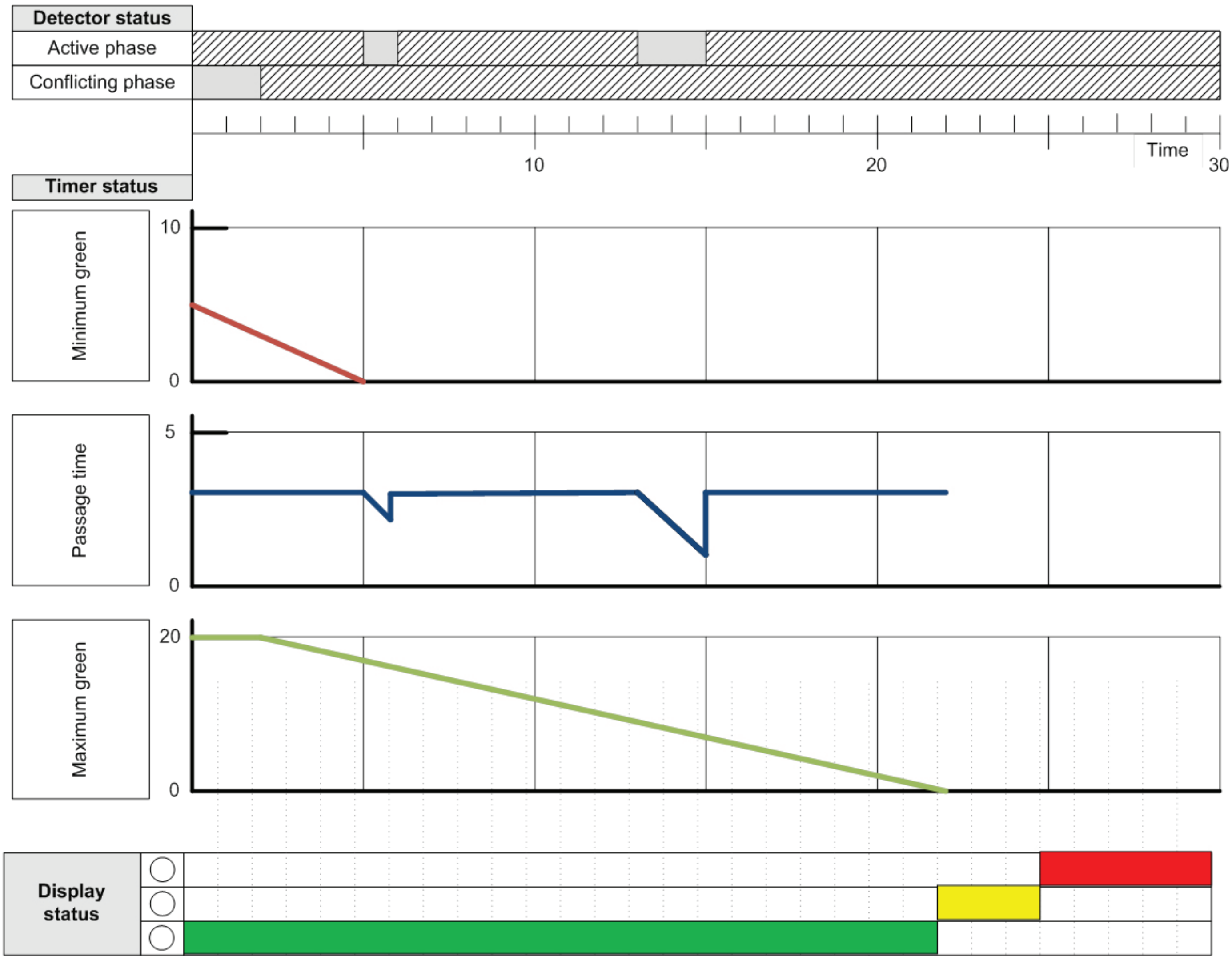


**Figure 11.** Traffic control process diagram

## Field Observations

Let's now move to the field. You are at the intersection of State Highway 8 and Warbonnet Drive in Moscow, Idaho. What geometric information do you see in the photographs of this intersection presented Figure 12 and Figure 13?

**Figure 12.** Aerial view of SH 8 and Warbonnet Drive

**Figure 13.** Street level view of SH 8 and Warbonnet Drive

We note first the geometric layout and that it is a T-intersection. State Highway 8, the major arterial, has two through lanes on both approaches, a left turn lane, and a right turn lane on the westbound approach. Warbonnet Drive, the minor street, has two lanes on the southbound approach.

There are also several other physical components of the intersection. The vehicle displays are mounted on the mast arms above each approach as shown in Figure 14. Also visible are lighting and street signs, as well as pedestrian crosswalks and other lane striping. The cabinet, housing the traffic controller and other devices, is located on the northwest corner of the intersection and is shown in Figure 15.

**Figure 14.** Mast arm, lighting, signs, and signal displays

**Figure 15.** Cabinet housing traffic controller

Figure 16 shows the inside of a typical cabinet. The call for service from the detectors goes to the detector amplifiers, located at the top part of the cabinet. These calls are then routed to the traffic controller, where they are processed according the timing parameters and logic that have been set. Finally, the load switches set the proper display, based on the outputs from the controller.

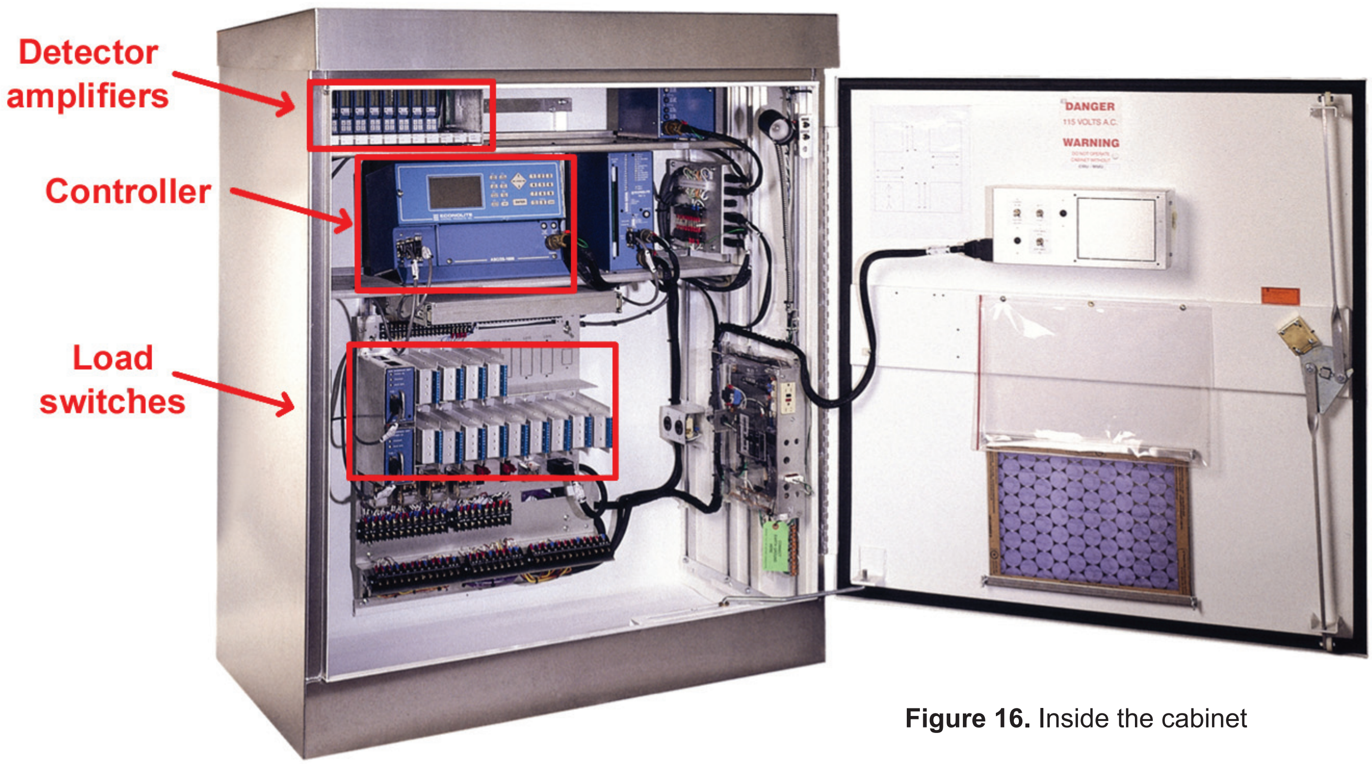


**Figure 16.** Inside the cabinet

Let's now focus on the flow of the vehicle users through the intersection, specifically on the westbound approach as shown in Figure 17.

**Figure 17.** Westbound approach and vehicle displays for eastbound lanes

**Figure 18.** Vehicle queue on westbound approach during red

We start observing the vehicle movements at the beginning of the red interval for the westbound approach. At the beginning of the red interval, as shown in Figure 18, vehicles respond to the red signal indication by slowing as they approach the intersection and coming to a complete stop either at the stop line or behind a vehicle in front of them. Vehicles queue up at the stop line with the queue growing as the red interval times.

**Figure 19.** Queue moving at beginning of green

**Figure 20.** Queue moving at beginning of green showing headways

When the displays change to green, vehicles begin to enter and cross the intersection (Figure 19). The driver in the first vehicle at the stop line sees the change in the signal and reacts to the change by accelerating his vehicle into and through the intersection. Drivers in the following vehicles begin the same process: they see the change in the signal, they see the vehicle in front of them begin to move, and then they begin to accelerate their vehicle into and through the intersection. As the drivers of the vehicles approach their desired speeds, the headways between the vehicles drop to a relatively constant or stable value, called the saturation flow rate. The queue that forms during red continues to be served (Figure 20).

After the queue clears, as shown in Figure 21, vehicles arrive at and leave the intersection without delay and without much change in their speeds. At some point, the signal changes from green to yellow (See Figure 22). A vehicle on the approach reacts to this change by deciding to stop. The display then changes to red so that the next set of movements can be served.

**Figure 21.** Vehicles arrive and leave without delay

**Figure 22.** Vehicle responds to yellow

In summary, the process that we've just observed through the photographs shown on the previous pages consists of four parts, each describing a response of the vehicle to the display:

- Drivers slow and stop as they arrive at the intersection during the red indication
- At the beginning of green, the queue begins to move as drivers respond to the green indication

- After the queue has cleared, vehicles respond to the green indication by arriving at the intersection and passing through without stopping
- When the yellow indication is displayed, vehicles either decide that they can safely travel through the intersection, or slow and stop in anticipation of the red indication

This flow process is one that you know well and have participated in as a driver many times. What is new is that you now have a context or framework for seeing and understanding this flow process and how it interacts with the other components of the traffic control system.