CHAPTER 1: THE TRAFFIC CONTROL SYSTEM: ITS PIECES AND HOW THEY FIT TOGETHER

This chapter includes information that you will need to prepare for, conduct, and assess each of the seven activities included in Chapter 1 of the student activity book. Figure 1 shows the various files that are available to support your works as you use these activities, including mini-lecture slides, solution files, and student resource files.

Chapter 1 The Traffic Control System	Mini-lecture slides	Solution files	Student resource files
A#01 Reading			
A#02 Assessment			
A#03 Discovery			
A#04 Discovery			
A#05 Discovery			
A#06 Design			
A#07 In Practice			

Figure 1. Support files

Figure 2 shows the kind of work required for each activity, how the activities might be grouped, and the approximate amount of class time required to complete the activity. The figure also identifies whether there is homework involved, a mini-lecture could be presented, student discussion could take place, and group work to do.

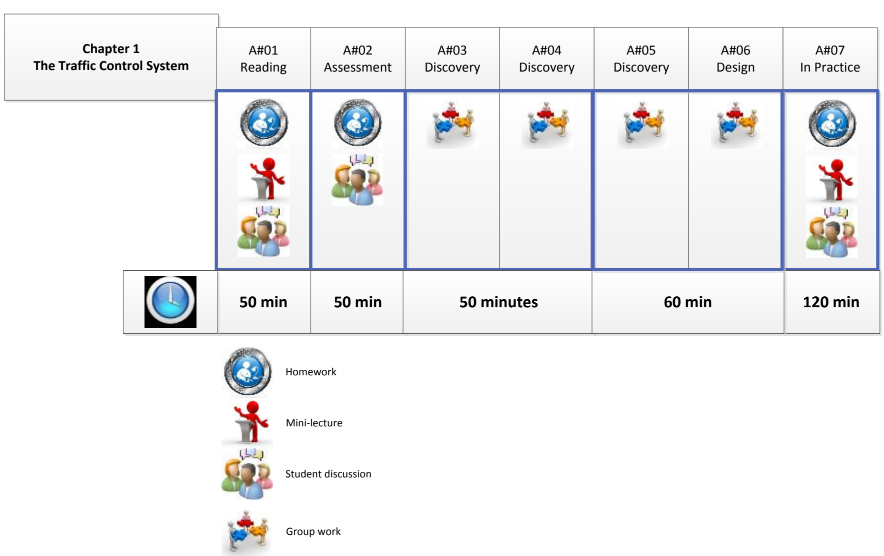


Figure 2. Activity work

Using Activity #1: Exploring the System and Providing a Framework (Reading)

Overview

This activity requires the student to read the "Information" section, define the terms listed in the Glossary, and answer the "Critical Thinking Questions." This activity is generally assigned as homework. Students will learn about the basic components and operation of the traffic control system. The components described in the reading include the user, the detector, the controller, and the display. The Traffic Control Process Diagram illustrates the interactions of these four components. Basic traffic flow characteristics are illustrated with descriptions and photographs.

Options for Use

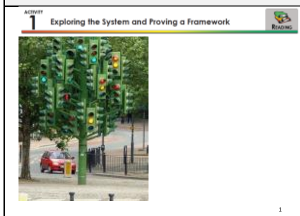
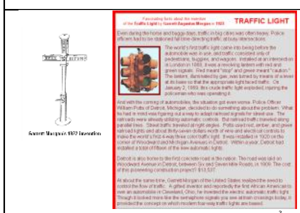
The reading ("Information"), defining the terms in the Glossary, and answering the Critical Thinking Questions are usually done as homework. After the students complete this work, the instructor has several options for assessing and clarifying student understanding of the reading during class:

- Quiz to assess their understanding and to hold them accountable for the reading. (15 minutes) As a way of encouraging students to complete a reading assignment in preparation for class, it is often useful to have a quiz or discussion to "test" their knowledge and to allow them to validate their understanding.
- Discussion and synthesis of the answers to the quiz, the glossary definitions, and answers to the critical thinking questions. (30 minutes) You can also facilitate discussion on the reading by allowing the students to discuss their responses to the quiz questions and the Critical Thinking Questions that were assigned as part of this activity. This discussion/synthesis is group work that allows students to review their quiz answers, as well as their answers to the Critical Thinking Questions and Glossary definitions with other students.

Preparing for the Activity

- Decide which of the options you want to do during class.
- Prepare for the class by reviewing Activity #1, including the "Information", the Glossary definitions, and Critical Thinking Questions and answers.
- Review the script to determine which parts of it that you want to use during class. And, review the slides that you want to include, based on your decision regarding the script.

Doing the Activity (Script)
(slides01.pptx)
The following script can be used along with the slides for this activity. The script and slides can be modified based on your needs and what you decide to emphasize for the activity.

Slide	Notes
	Provide your perspective on the reading that they have just completed and how it fits into the course. Discuss how this reading fits into chapter 1, as an introduction to the topic of traffic signal control systems.
	Why traffic signal systems? William Potts, a Detroit police officer, is generally credited with inventing the first modern three color, four direction traffic signal in 1920.
	Among various designs that were being developed, Garrett Morgan was one of the first to receive a patent for the design of the electric automatic traffic signal. [**Read the following**] From: http://inventors.about.com/od/mstartinventors/a/Garrett_Morgan.htm After witnessing a collision between an automobile and a horse-drawn carriage, Garrett Morgan took his turn at inventing a traffic signal. Other inventors had experimented with, marketed, and even patented traffic signals, however, Garrett Morgan was one of the first to apply for and acquire a U.S. patent for an inexpensive to produce traffic signal. The patent was granted on November 20, 1923. Garrett Morgan also had his invention patented in Great Britain and Canada. Garrett Morgan stated in his patent for the traffic signal, "This invention relates to traffic signals, and particularly to those which are adapted to be positioned adjacent the intersection of two or more streets and are manually operable for directing the flow of traffic... In addition, my invention contemplates the provision of a signal which may be readily and cheaply manufactured."

Slide	Notes
	From: http://www.therepublic.com/view/story/3795d8a4d70a4b13800dee0425c7db34/UT--Celebrating-Stoplights Shannon Dininny, Associated Press, 4 October 2012 “Salt Lake City — Pedestrians, horses, trolleys — and a growing fleet of automobiles — clogged early 20th Century streets in America. Travel was slow, navigation dangerous, and traffic cops stood amid the chaos at their own peril. Enter Lester Farnsworth Wire, the dean of Salt Lake City's inaugural traffic squad and arguably the inventor of the world's first electric traffic light in 1912: A birdhouse-like box with red and green bulbs on each side to signal stop and go to travelers. Wire is one of several men who lay claim to the title "Stoplight Inventor," but Utah celebrated the 100th anniversary of his creation Thursday with a new display that includes a replica of the original signal….” Utah also installed the first inter-connected traffic signal system in the world in 1917, with lights at six intersections controlled simultaneously from a single switch. But first appeared the original stoplight, a creation that came to be known as "Wire's Bird Cage" and "Wire's Pigeon House," according to research by Linda Thatcher of the Utah State Historical Society in 1982. So Wire built a wooden box resembling a birdhouse and installed two bulbs on each side — one bulb dipped in green paint, the other dipped in red paint. The box sat in the middle of the intersection and, once connected to overhead trolley wires, enabled officers from the side to flip a switch and direct traffic.
	In transportation, we worry a lot about congestion. But congestion has been around as long as we have gathered in cities. Here is Cleveland, Ohio in 1915. “Taylor also said he doesn't think Wire had a patent for his invention, which explains the competing claims about the world's first traffic signal. “As early as 1868, a device with an arm that extended horizontally signaled stop and, when at a 45-degree angle, caution. And in 1914, a system in Cleveland, Ohio included four pairs of red and green lights, each mounted on a corner post and manually operated by a switch inside a control booth. That system was patented in 1918 by James Hoge, according to History.com the website for The History Channel.”

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<tr><th>Slide</th><th>Notes</th></tr>
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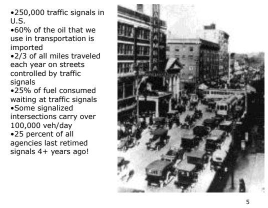

</td><td>Why do we consider traffic signals to be important as we talk about congestion?
[see list on slide]</td></tr>
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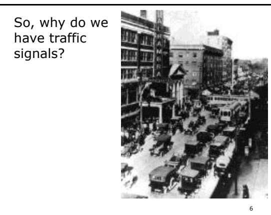
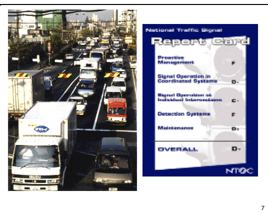


</td><td>Why traffic signals? [Ask Them]

Two answers
To keep cars from running into each other [safety]
To make sure cars don’t stop, or don’t stop for too long (performance]</td></tr>
<tr><td>


</td><td>But we are not doing a good job nationally in managing our signal systems and the congestion that results from too much traffic and/or poor signal timing practices. This slide shows the results of a report card from the National Transportation Operations Coalition (NTOC) that has been done at least twice since 2007, and is about to be done again. It is really a self-assessment done by traffic engineers from around the U.S.</td></tr>
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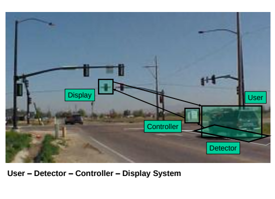

</td><td>So, what is a traffic signal system?
Let’s first look at the system components and how they interact.
Users respond to display
Detection system responds to user
Controller responds to detector
Display responds to controller
The relationship of each of these components is a very important one, and we will come back to it a number of times this semester.</td></tr>
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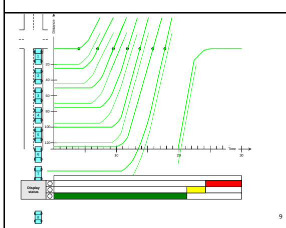
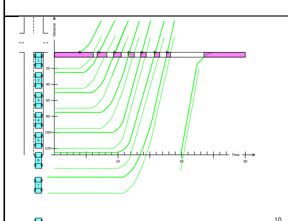


</td><td>Let’s look at each of these interactions separately. What do we see in this slide? [ask them] [there are many rich details, starting with seven cars in queue, an eighth about to join the queue, and the eighth vehicle not making it through the intersection]
Time space diagram
Vehicle trajectories
The vehicles respond to what is displayed
[This is the response of the user to what is being displayed.]</td></tr>
<tr><td>


</td><td>Here is the second interaction of a pair of components that we looked at before. Let’s say that there are loop detectors that are located at the stop bar. Again, we note the time-space trajectories of vehicles moving through the intersection, and now passing through the detection zone. When a vehicle is present, the detection zone is occupied. This is the interaction of the user and the detection system.</td></tr>
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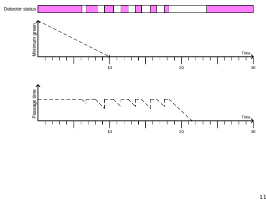
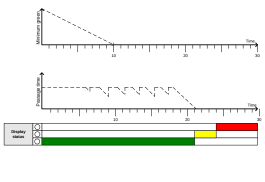
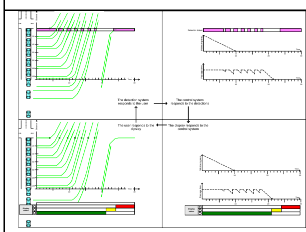
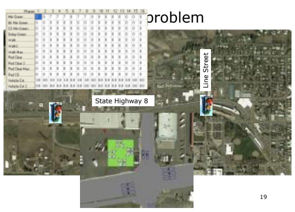
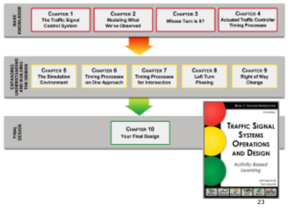
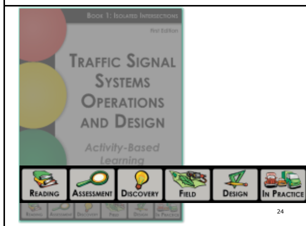
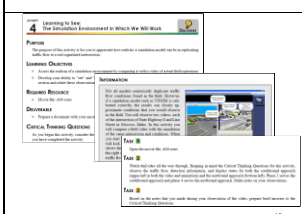
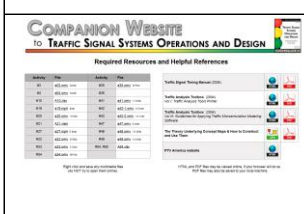
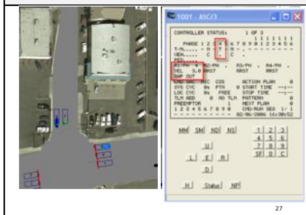
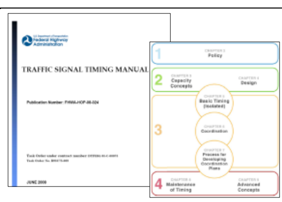
Slide	Notes
	When the detection zone is occupied, a call to the controller is active, and the controller responds. The controller has a variety of timing processes that respond to these vehicle calls. We see here two of the timing processes. For example, the minimum green timer begins at the beginning of the green indication and times down, here reaching zero (or expiring) at 10 seconds after the beginning of green. This also shows the passage time (which we will learn about later) that helps to determine when the green should end. This is the interaction of the detection component and the signal controller component.
	Finally, as a result of the timing processes in the traffic controller, the various signal indications are displayed. For vehicles, these are green, yellow, and red. This is the interaction of the signal controller and the display: one drives the other.
	Here we see the system as it works together with each of these component relationships. We will learn about each of these four components individually as you prepare your designs this semester. A caveat: there is a lot of information portrayed in these charts. Don't feel intimidated yet! We will go over all of this very methodically during the semester.
	Another important view: here is a system of signals from downtown Portland, Oregon. We will consider a system as part of your second design project.
	Another view of the downtown streets, showing the 200 foot block spacing
	This slide begins to show the multimodal nature of users: bike box

Slide	Notes
 17	Another user group: pedestrians
 18	Still another user group: public transportation All of these are important to consider. But to get us going in learning about signal systems, we will focus primarily on the vehicle mode: drivers and vehicles.

 19	Now, let's look briefly as what you will be doing during the semester. You will be responsible for developing two signal timing plans
	• The first design is for a single intersection. As part of this design, you will:
	  ○ [S] Develop the timing plan
	  ○ [S] Develop the phasing plan
	  ○ [S] You will then develop a timing plan design for a system of four intersections in Moscow to coordinate the signals in a system in which you will consider the cycle length, the splits, and the offsets.

Introductions and background • Find someone that you don't know • In 5 minutes, find out their name and two things about them • Also find out what their specific interest is in transportation • Be prepared to introduce them to the rest of the class using the information that you learn about them 20	[optional: ice breaker/introduction]
Syllabus • About the course • What you will do • Meeting times • Course instructor • Textbooks • Assignments, exams, expectations • Learning styles • Schedule 21	[optional: course syllabus]
 22	[optional: course web site]

Slide	Notes
	The textbook for the class is called “Traffic Signal Systems Operations and Design”. This is the book that will cover the first two-thirds of the class. There are ten chapters in the book. The first four established the base knowledge that you will need to understand how traffic control systems work. The second section, chapters 5 through 9, will be building the parts of your design, in a step by step manner. In chapter 10, you will complete and present your design.
	The book contains 63 activities, divided into these ten chapters. Each chapter includes a set of activities including: • **Reading**: providing information on the topics covered during the chapter. • **Assessment**: in which you will have the chance to test and apply what you learned in the reading. • **Discovery**: opportunity to discover new factors or perspective about the chapter topic by observing animations, collecting or analyzing data, or making calculations. • **Field**: connect the theory that you have learned with what you see in the field. • **Design**: Determine one component of your design and evaluate its performance. • **In Practice**: compare your design with recommended practice.
	Each of the activities has a consistent format: • Purpose: what the activity is about and why it is worth doing • Learning objectives: what you will know and be able to do after you have completed the activity • Required resources: what you will need to complete the activity • Deliverables: what you will produce • Critical Thinking Questions: deeply and thoughtfully consider what you learned • Information: additional ideas or note to help you complete the activity • Tasks: specific steps that you will follow
	There is a companion web site (see link on the class web site) that has all of the supplemental material that you will need, including animation files, data files, and tutorials for VISSIM and Excel.

Slide	Notes
	My perspective: • Understand the system • Activity based learning • Learn to see, interpret, integrate • Understand system to design it 1. Look at side by side simulations: what are the traffic conditions 2. Look at the controller screens It is also important to mention my philosophy of class time. I make little or no distinction between what we traditionally call lecture and lab. We will have some times in which I will lecture and sometimes in which you will be doing work or activities. It is critically important that you come to class prepared, having completed whatever assignment is due that particular day. I truly believe that the more active that you are in class, the more you will learn. It will be very common for us to have an assignment the day before, often readings or problems, with critical thinking questions that will help to focus your work. You will be responsible for answering or discussing these questions at the next class session. These questions will help to facilitate your preparation for each class. Please take them seriously. And there will be quizzes from time to time to encourage responsible preparation for classes. Note the model for most classes: 1. Preparation assignment so that you will be ready to work during class 2. Work during class 3. Homework assignment based on work during class
	We will also be using the standard industry reference guide, the Traffic Signal Timing Manual. It was written primarily by Peter Koonce, now signal systems engineer for the City of Portland. The best reference available today on best practices on traffic signal timing. (Contract for update is in process; Peter is chairing the panel that will oversee this work which will be completed next year) This book is available at the book store and you will use it throughout the semester.
	Some cautions from previous students and classes [see list]

Slide	Notes
	Do quiz: This is an individual work. Four questions. Ten minutes. • What are the four main components of the traffic control system and how are they interrelated? • What are the types of users of the system? • What is actuated control and when do you think it is preferable to fixed time control? • What are the discrete time periods of flow during a cycle?
	• Pair: Discuss/review quiz answers. Review your answers and synthesize if need to produce better/final answer. • Pair: Review Glossary and CTQ from A#1 with partner. Synthesize your answers; be prepared to report on (1) areas that you feel that you understand, (2) areas that you would like to discuss more, and (3) develop a set of up to three questions that you still have on this material. • Class discussion and sharing on A#1 and quiz results. • Collect quiz You can also facilitate discussion on the reading by allowing the students to discuss their responses to the quiz questions and the Critical Thinking Questions that were assigned as part of this activity. This discussion/synthesis is group work that allows students to review their quiz answers, as well as their answers to the Critical Thinking Questions and Glossary definitions with other students. Instructions to the students for this group work: 1. Work with a partner to review the answers to the quiz questions. Determine if your answers are correct or not. Prepare a synthesis of your collective answers to the quiz questions. 2. Review your answers to the critical thinking questions with your partner to identify the points that you understand and that you don't understand. Be prepared to report on the issues that you feel you understand and the issues that you would like to discuss more so that you can improve your understanding. Develop a list of three questions that you have on this material.

Solutions

The solutions presented here include:

- Example quiz questions and answers
- Glossary definitions
- Answers to critical thinking questions

Example Quiz Questions

1. What are the four main components of the traffic control system and how are they interrelated?

- The four main components of the traffic control system are the user, the detector, the controller, and the display. Each of the four components is connected to two other components. For example, the user is the input to the detector and the output of the detector influences the controller.

2. What are the types of users of the system?

- Example user types include: passenger car driver, truck driver, transit riders, pedestrians, and bicyclists.

3. What is actuated control and when do you think it is preferable to fixed time control?

- Actuated control responds to traffic demand variations; it is preferable to fixed time control when there is variation in traffic demand.

4. What are the discrete time periods of flow during a cycle?

- The discrete time periods of flow during the cycle are: during the red, the initial portion of green when the queue is clearing, and the final portion of green after the queue clears.

Glossary Definitions

Term	Definition
Actuated control	Traffic control in which the duration of the green times varies, based on the level of traffic demand.
Detector	A sensor designed to detector the presence of a user who desires service.
Display	A set of indications that provide information to the users on what to do as they approach or are stopped at the intersection.
Fixed time control	Traffic control in which the duration of the green times are fixed.
Movement	Groups of users.
Queue	A line of users (vehicles) that form at the intersection.
User	An entity that desires service at the intersection.

Answers to Critical Thinking Questions:

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

- Fixed time control is appropriate when traffic demand is constant or doesn't vary much. A set amount of green time to serve each movement can be determined in advance. This is why this type of control is often referred to as pre-timed control. Fixed time control is also used when several intersections are coordinated and the beginning of green needs to occur at the same point in the cycle, so that the green band appears at the same time for vehicles arriving from the upstream intersection. By contrast, actuated control depends on the flow of traffic: literally the rate of traffic demand or the arrival at each individual vehicle "actuates" the traffic signal. Actuated traffic control is appropriate when traffic demand varies from cycle to cycle and the length of the green depends directly on the number of vehicles that arrive at the intersection. So, when demand is low, the green duration can be shorter than when demand is higher and a longer green duration is required.

2. Describe the interrelationships that are shown in the two figures between the components of the traffic control system?

- Four interrelationships are shown between the detector, user, controller, and signal display. The detector detects if a vehicle is present and sends information to the traffic controller. The controller responds to the information received from the detector and determines what status the signal should display. The signal then displays status determined by the controller. Users see the signal display and react, either continuing through the intersection or stopping. As the user approaches the intersection, they are detected by the detector. The user demand and the intersection geometry are the inputs to this system while performance is the output of the system.

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

- There are several measures that can be used to determine the performance of the traffic control system. The most common measures are average delay per vehicle (or user), the queue length (mean, 95%), and the v/c ratio. The first two are directly perceivable by the user; all three are useful to the traffic engineer. There are other measures that are more specific to the traffic control system including utilization of green time.

- To measure delay, the free flow travel time and the actual travel time would be needed. To measure travel time, the time that the vehicle is in the system would be needed. You could also measure the safety provided by the intersection by reviewing accident reports. These reports might be used to determine how many accidents could be attributed to the signal timing, for example if the clearance intervals are not sufficiently long, an increase in crashes could be observed when compared to intersections with sufficient clearance time.

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

- The physical elements of the intersection include: the physical layout or geometric elements (lanes, lane usage, width, bike lanes, stripping, angle of approaches), the traffic control elements (controller, cabinet, displays, detectors), and other elements (lighting, electrical, power supply, communications linkages).

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.

- We often assume uniform vehicle arrivals when first learning about intersection operations, but we learn soon that they could be random (when flow is low) or platooned when there is an upstream signal that controls vehicle arrivals). For departing vehicles, there are three periods: flow is zero during red, saturation flow during the initial portion of green when the queue is clearing, and equal to the arrival rate   after the queue has cleared and vehicles arrive and depart without delay.

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

- Student responses to question six are expected to vary.

Using Activity #2: What Do You Know About Traffic Signal Systems? (Assessment)

Overview

The objective of Activity #2 is to determine students' preexisting knowledge of intersection operations developed during earlier courses in transportation engineering. This is done to help you as the instructor to know the range or levels of competency and background preparation of the students in the class.

Options for Use

This activity is generally done in class.

- Completion of activity questions by individual students during class.
- Discussion of responses to questions.

Preparing for the Activity

- Confirm options for class period.
- Review questions and answers.
- Consider how you might engage students after they have completed the activity, reinforcing and clarifying what they have learned.

Doing the Activity (Script)

The following script can be used along with the slides for this activity. The script can be modified based on your needs and what you decide to emphasize for the activity.

Slide	Notes
[none]	**Tell**: The purpose of the activity is to see what you remember from the introductory course that you have completed in transportation (or other previous courses). This test will not be graded; however, it will provide you with the chance to see what you know and what you still have to learn.
	Do: Distribute quiz form. Do: Invite the students to read through the activity. Ask if they have any questions on the activity.
	Tell: this is individual work. Fill out Q1-Q10 on form. Circle answers only plus sketch for Q9. No name, no grade. **Tell:** complete answers in book for Q1-Q15, with justifications; we'll take about 15 minutes or so for this work.
	Collect: forms.
	Pair: discuss/review A#2 answers with partner. Synthesize best answers.
	Class discussion: on best answers; identify issues that they don't understand or would like to discuss more.

Solutions

Answers to Critical Thinking Questions

1. Assume that traffic arrives at a signalized intersection with uniform flow (equal space between each vehicle). At what point during the cycle will the queue length (number of vehicles in the queue) be at its maximum?

- The answer is "c": at the beginning of green. The queue builds during red and decreases during green, *so will be at its maximum value at the end of red or beginning of green*.

2. What is the effect of long cycle lengths at a signalized intersection (as compared with shorter cycle lengths)?

- The answer is "b: the delay is increased. Longer cycle lengths mean longer red times, which result in queues that take longer to clear.
  Answer from Anuj: If all-red time is being used for an intersection the width of intersection is not used for calculating the yellow duration. Which is the case in some states.

3. What is the purpose of the yellow indication at a signalized intersection?

- The answer is "c": both "a" and "b". The yellow indication must give a vehicle either adequate time to stop or adequate time to safely clear the intersection.

4. Which factors should be considered when determining the duration of the yellow indication?

- The answer is "d": some combination of a, b, and c. All three factors are important.

5. Suppose traffic signal control will replace stop sign control at an intersection. Which of the following will likely result?

- The answer is "c": some movements will experience more delay and some movements will experience less delay with signal control.

6. Suppose a platoon of ten vehicles departs from a signalized intersection when that signal display turns green. When this platoon arrives at the next signalized intersection downstream, the length of the platoon as measured from the front of the first vehicle to the end of the last vehicle will have:

- The answer is "b": The platoon expands as it travels from one intersection to the next.

7. If the green time is increased for one approach at a signalized intersection, the delay for the approach will likely:

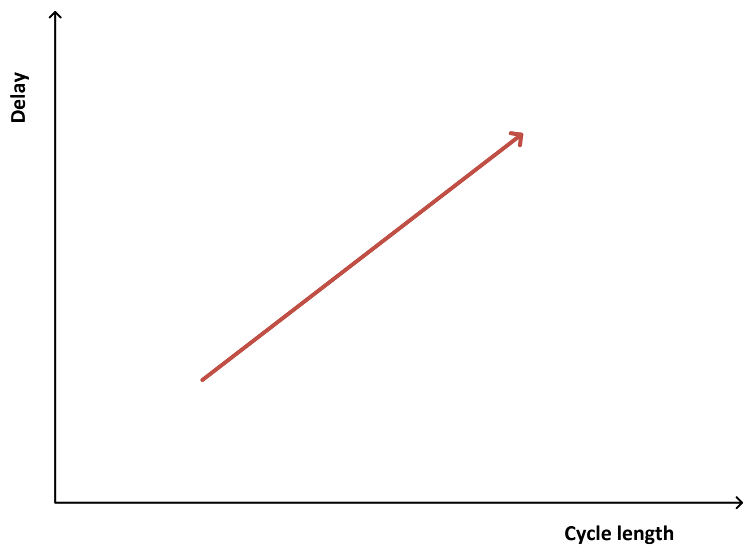
- The answer is "b" since additional green time will mean that vehicles will be less likely to stop and wait. However, it could also increase, if the additional red time for other approaches causes queues to grow on these approaches.

8. If the green time is increased for one approach at a signalized intersection, the delay for the entire intersection will likely:

- The answer could be "a" or "b". The likely result is "a" since additional red time on the other approaches may result in an increase in delay overall.

9. Prepare a sketch showing the relationship between delay and cycle length showing cycle length on the x-axis and delay on the y-axis.

- The sketch below shows that, in general, the delay increases as cycle length increases. But, for very low cycle lengths, the delay also increases.



10. The time that the green interval is displayed should be based on…:

- The correct answer is "a". The objective that we will emphasize is to provide enough time to serve the vehicles that arrived during the previous red interval, but no longer.

11. What is the purpose of a signalized intersection?

- The primary purpose of a signalized intersection is to separate conflicting movements to maximize safety. The secondary purpose is to maximize the capacity and minimize delay for all users of the intersection.

12. What is the difference between pre-timed signal control and actuated signal control? In what situations would pre-timed control be better; and in what situations would actuated control be better?

- Fixed time control is appropriate when demand is relatively constant. Actuated control is appropriate when traffic demands are variable.

13. What measures would you consider to determine how well or poorly a signalized intersection is performing?

- Performance measures could include delay, queue length, travel time, and volume/capacity ratio.

14. If you were standing in the field near a signalized intersection, what would you look for to determine if the intersection was performing well or performing poorly?
- Do the queues clear before the end of green, does the traffic from one lane affect the operation of adjacent lanes or an upstream intersection, do pedestrians feel safe when crossing the intersection.

15. Consider that you are the traffic engineer responsible for the signal timing operation for the intersection shown in the figure. Citizens have called your office and complained that they often have to sit through three or more cycles during congested periods and this makes a significant difference in their travel times and fuel costs.
    a. What information or data would be required to properly analyze the situation?
- Traffic counts could be used to determine the expected number of vehicles using the intersection during peak times.
- Cycle length and green times could be measured to assist in the estimation of delay.
- Saturation flow rate could be used in conjunction with the traffic count to determine how much green time should be allocated to each movement.
- Delay data could be measured to help determine performance.

    b. How would you quantify the performance of the signal system with the data you collect?
- Compare the capacity of the intersection with the traffic demand.
- Estimate the expected delay.

[Note: Need to provide more details such as to whether right turn from ramp has a signal and can be metered.]

Using Activity #3: Exploring the System: Driving Along an Arterial and Noting What You See (Discovery)

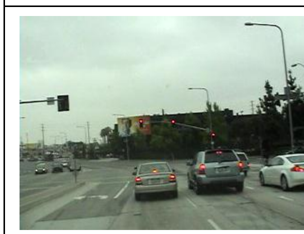
Overview
In this activity, students will "travel" with a vehicle driving along an arterial with four signalized intersections using a movie file. It is designed to help students change their perspective from that of a driver to that of a transportation engineer. This activity gives the students to see what happens at a signalized intersection and how vehicles respond to the basic elements of an intersection.

Note that the video is a little amateurish; that is, it was filmed by NGSIM staff just to show one of the sites for the NGSIM study and was not intended to be a "final" production-perfect video. However, it does allow the student to get engaged with the process of traveling down the arterial.

Both Activity #3 and Activity #4 can be conducted sequentially during the same class period.

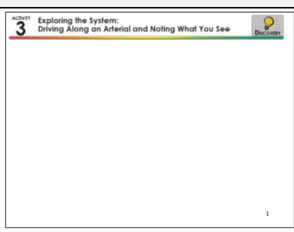
Options for Use
- This activity (along with Activity #4) can be done in class in groups or pairs of students depending on the availability of classroom computers. Allow time for watching the video and for students to make notes (about 10 minutes) and then to discuss their findings (about 15 minutes).

Preparing for the Activity
[File: a03.wmv]
- Read through the activity to familiarize yourself with the tasks that the students will do.
- Review the NGSIM project to provide some perspective to the students on why this video was made.
- Watch the video (3:42), using the following notes as a guide:

Slide	**Notes**
 NB, intersection 1	The vehicle approaches the first intersection, the off-ramp for US 101, located on the right side of the arterial. There is a display located on the near side approach to the intersection showing a green arrow. There are two displays located on mast arms located on the far side of the intersection. Both displays show a green indication. In response to the green indication, and with no other vehicles close enough to affect it, the vehicle passes through the intersection with no apparent delay. (time = 0:08)
 NB, Intersection 2	The vehicle approaches the second intersection (Campo de Cahuenga). The displays are located on the mast arm. Two displays (showing green) are for the through and right turning traffic, while a third display shows a red indication for the left turning traffic. Again the display shows a green indication and in response to this indication the vehicle passes through the intersection with no apparent delay. (time = 0:19)
 NB, Intersection 3	The vehicle approaches the third intersection (Main Street). Three displays are located on the mast arm, and each provides information to the through and turning vehicles entering the intersection. A fourth display (not immediately visible) is located on the left side of the intersection. As the vehicle approaches, the signal changes to yellow and then to red. In response to these indications, the vehicle slows and then stops. (time = 0:32) The display at Main Street turns from red to green and the vehicle responds to the green by accelerating from the stop line and entering the intersection. (time = 0:58)
 NB, Intersection 4	The vehicle approaches the fourth intersection (James Stewart Avenue) as the signal changes from yellow to red. In response, the vehicle slows and comes to a stop. The three signal heads control the movements of all vehicles, both through and turning. (time = 1:07) The signal changes to green and the vehicle responds to the display by beginning to enter the intersection. However, there is an opposing queue that prevents the vehicle from completing its left turn movement. (time = 1:22) The opposing queue finally clears and the vehicle completes its left turn movement, with the display still showing a green indication. (time = 1:47)

Slide	Notes
 SB, Intersection 3	The vehicle arrives at Main Street. The display is green and the vehicle travels through the intersection with no display. (time = 2:03)
 SB, Intersection 2	The vehicle arrives at the Campo de Cahuenga intersection in one of the two left turn lanes. The display is red, and the vehicle responds to the display by coming to a stop. (time = 2:14) A green arrow is displayed for the left turning vehicles and the queue begins to move in response to this display. (time = 3:02)
 SB, Intersection 1	The vehicle arrives at the US 101 intersection while the red signal is displayed. In response, the vehicle slows and stops. (time = 3:30) The display shows a green indication and the queue begins to move in response. (time = 3:32)

Doing the Activity (Script)
[Slides: slides03.pptx
The following script can be used along with the slides for this activity. The script and slides can be modified based on your needs and what you decide to emphasize for the activity.

Slide	Notes
	Invite the students to read through the activity. Ask if they have any questions on the activity. **Tell**: The purpose of both activities (A#3 and A#4) is to learn to see and observe, and to discern what is important relating to traffic flow and signalized intersection operations. For example, when you are driving down on an arterial to get some place, you: • Drive defensively to keep safe. • Watch for other cars and pedestrians. • Watch the signal displays or stop signs. **Tell**: Much of the learning in this class depends on observations and what you learn from these observations. We sometimes call this process scaffolding, continuing to build on what you know with this new knowledge that you develop. A#3 and A#4 are an important part

Slide	Notes
	of this process and we will do them both this hour. The instructions need to focus on the questions that they will be asked to do: do the queues clear? Do you arrive at the intersection and not have to stop? What are the examples of signal timing that they can see and observe? How is LT treated? Are there other operational issues.
	Tell: But as you learn to think like a traffic engineer, you will begin to watch for other things: • The relative flow rates or volumes. • How the intersection is laid out, the stripping of the lanes. • The location of information, guide, and warning signs. • The location and operation of signal displays. • The location of the cabinet. • How the intersection is performing (do vehicles arrive primarily on red or green, do queues clear before the end of green, is there queue spillback from the downstream intersection, can pedestrians cross safely.
	This activity is a tour of the Lankershim Blvd site. You can see the driver interacting with the system. I want you to learn several things: (1) watch for the street furniture components, (2) link performance with what they observe, (3) introduce concept of “what” and “how” to see. The text needs to provide clearer instructions on this. What do I want them to look for and think about?
	Tell: In Activity #3, you will take a tour of the Lankershim Blvd. site. This tour includes four signalized intersections. You can see the driver interacting with the system. I want to you to learn several things: (1) watch for the furniture components, (2) link performance that they observe, (3) introduce concept of “what” and “how” to see. What do I want you to look for and think about? Do the queues clear? Do you arrive at the intersection and not have to stop? What are the examples of signal timing that they can see and observe? How are left turns treated? Are there other operational issues?
	Here are some slides that will show you the area you about to see: • Aerial view showing building where video was shot. • Lankershim Blvd intersection using Google Streetview. In this slide you see a portion of Lankershim Blvd in Los Angeles, and the NBC Universal building, on top of which the data were collected for the NGSIM or next generation simulation project by the Federal Highway Administration. We will use the NGSIM data several times this semester. For now, in A#3, you will take a tour of Lankershim

Slide	Notes
	Blvd, to help make this transition from driver to transportation engineer.
	Here is a street view of Lankershim.
	Invite them to watch the video.
	Tell: You are asked to write a one page paper discussing the physical layout of the approach, and describing how the drivers (users) interact with each other and more importantly with the display. In the user-detector-controller-display relationship, this activity focuses on the user-display aspect.
	Then (messy video): • **Pair:** Work through activity • **Pair:** Develop answers to three questions • **Deliverable/Pair:** Word document due tomorrow. • **Class discussion:** classify what you observed into volume/demand, geometry, control, and performance.

Solutions
The notes under "Preparing for the Activity" provide guidance for reviewing student work.

Some notes for the solution:
Intersection 1
- Geometry: One through left lane and one through right lane.
- Display: The display was green when the driver got to the intersection and proceeded through the intersection.

Intersection 2
- Geometry: One left turn bay, two through lanes, and one through right lane.
- Display: The display was green when the driver got to the intersection and proceeded through the intersection.

Intersection 3
- Geometry: One left bay, three through lanes, and one right bay.
- Display: The display was red when the driver got to the intersection, stopped and then waited for the display to change to green. Once the display changed, the driver preceded though the intersection.

Intersection 4

- Geometry: One left bay, three through lanes, and one right bay.
- Display: The display was red when the driver got to the intersection, stopped and then waited for the display to change to green. Once the display changed to green the driver did not go because he was at a permitted left turn. Once it was safe for the driver to proceed he did.

Using Activity #4: The Simulation Environment in Which We Will Work (Discovery)

Overview

In this activity, students will learn the simulation model VISSIM and how it can be used to evaluate signal operations. The goal of Activity #4 is to allow students to observe how realistically a simulation can model actual traffic. The video shows a recording of an intersection on the right and a VISSIM simulation of the same intersection on the left. The key thing for students to observe is that there are only minor differences between the two videos, indicating that if the simulation is calibrated correctly, actual traffic conditions can be accurately modeled. Furthermore, students should observe that the simulation models traffic in a similar fashion to what is described in Activity 1, indicating that the simulation models driver behavior well.

Note that the video shows a simulation that may be “too good to be true”. Both perspectives can be used in discussion with the students about the role of simulation and what to expect when using simulation models.

Options for Use

- This activity is often conducted together with Activity #3. While the activity can be assigned as homework, doing it in class allows discussion to take place while it is still fresh in the minds of the students.
- Allow students about 10 minutes to watch the video and make notes, and another 15 minutes to discuss their answers to the questions.

Preparing for the Activity

- Read through the activity that to familiarize yourself with the tasks that the students will do.
- Watch the video so that you are familiar with its contents.

Doing the Activity (Script)

The following script can be used along with the slides for this activity. The script and slides can be modified based on your needs and what you decide to emphasize for the activity.

Slide	Notes
[no slides]	Invite the students to read through the activity; ask if they have any questions on the activity. Have them pair off with another student.
	Tell: Now we will introduce the simulation environment that you will work with, VISSIM. Here is an example movie made from VISSIM, as an example. [show movie file]
	Tell: One of the questions that people often ask: How realistic is the simulation? That is the purpose of this activity.

Slide	Notes
	Emphasize the learning outcome for this lesson: Be able to determine how realistic the simulation environment is by comparing it with a video of actual field operations.
	Tell: In this activity you will compare a field video with the simulation of the same intersection and conditions. When you start the movie file using Windows Media Player, your computer screen will look like this.
	Tell: Three detector status indicators and the phase-2-green indication are imprinted in black boxes on the video frames. When a detector is "ON", the black text box corresponding to the detector is filled with the name of the detector. The detector names are indicated in parentheses in the figure. When the phase 2 green is "ON", the corresponding black text box is filled with "P2", for phase 2.
	Tell: The two circled vehicles are queued in both fields of view and are calling for service on phase 2 as can be seen by the fact that the stop bar detector is on.
	Invite them to watch the video.
	Tell: Take about 5-10 minutes to watch the video and make notes.
	Discuss their notes and observations using the Critical Thinking Questions.

Solutions

Answers to the Critical Thinking Questions

1. How realistic does the simulation appear to be? How realistic does a simulation model need to be? What is the basis of your conclusions?

- The movie file shows how realistic a simulation model can be. Each vehicle arrival in the field video is duplicated almost exactly in the VISSIM animation. This degree of realism is important to note as we will depend on these simulation tools to provide us with a realistic portrayal of field conditions as you learn more about signal timing.
- But there is another side to the degree of realism shown in the video. While it is possible to duplicate individual vehicle movements, which is important to know that individual driver behavior can be modeled with a high degree of accuracy, most simulations will never be calibrated to this point. Students should know that they should never expect this.

2. Based on the information provided in the video, how do you know that a southbound vehicle has been detected?

- The southbound vehicle was detected because the signal display changed to serve that movement. From the video it is clear that no northbound vehicles were present when the display changed meaning that only the southbound vehicles were available to be detected.

3. Is the process of queue formation and clearance for the southbound approach similar or not to the description of traffic flow in Activity 1?

- The queue formation and clearance performed exactly as described in Activity 1. Drivers slowed and stopped at the intersection when the display was red. 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 decide to either safely travel through the intersection, or slow and stop in anticipation of the red indication.

4. Why does the phase end (or the indication turn from yellow to red) for the southbound approach near the end of the video?

- The phased terminated due to a gap-out after the queues were cleared.

5. What other observations can you make that are relevant to the operation of the intersection?

- Students' answers to question five are expected to vary.

Using Activity #5: Working Together – Team Building for Effective Learning and Effective Design (Discovery)

Overview
In this activity, students will learn about effective team dynamics. The readings for this activity discuss different team roles, team dynamics and basic ground rules for groups. Teams of three to four should be assigned before class.

Options for Use
- This activity can be done as homework or in class, with students working with a partner or a small group.

Preparing for the Activity
- Review the three readings.
- Determine teams or groups in which students will be working for this activity and the subsequent team design activities.

Doing the Activity (Script)
The following script provides ideas for conducting the activity and can be modified according to the needs of the individual instructor.

Slide	Notes
	Announce teams. Assign reading: 10 minutes to read one document; 5 minutes to prepare outline.
	Tell: 1. Meet in your team. 2. Based on your assigned readings, identify 3-5 key things that you learned that will help you in creating your team (roles: captain, recorder, spokesman) (15 minutes) 3. Report on this list to class.

Solutions
The following notes were made by student teams for each of the three readings.

Outline for Teamwork Methodology:
Because teamwork is a process, the following methodology was given to further understanding and performance of teamwork:

1. Define the Mission: Establish a common vision and goals for the team.
2. Recruit Members: Assemble the individuals to meet the needs of the team.
3. Collect Resources: Identify and collect resources available to the team.
4. Build the Team: Assign members to appropriate roles.
5. Create and Implement Plan: Schedule the resources for identified tasks and perform the plan.
6. Assess Performance: Assess the performance of the team against the plan.
7. Modify the Plan: Make periodic improvements to the plan.
8. Provide Closure: Provide a final point or end; celebrate accomplishments

Outline for Designing Teams and Assigning Roles:
Establishing roles for each team member can increase the productivity of the team by allowing the individual team members to work independently but still be accountable for what their role was. The following ten roles were described, with each member having specific roles in addition to contributing to the group as an active learner:

1. Captain
- Be accountable for the overall performance of the group
- Ensure that the teamwork is enjoyable and rewarding for the team members and that all team members are learning

2. Recorder
- Record important information, data, and group decisions

3. Reflector
- Assess the performance, interactions, and dynamics of the team members
- Record strengths and weaknesses of the team members

4. Spokesperson
- Speaks for the team

5. Technology Specialist
- Masters the technology available for the activity
- Helps others lean the technology

6. Planner
- Develop a plan to complete the activity
- Helps the team stay on the plan

7. Timekeeper
- Keeps track of time worked for each task

8. Optimist
- Keep the team positive
- Looks for ways in which discoveries can benefit the team

9. Skeptic
- Question assumptions made by the team
- Quality control

10. Spy
- Eavesdrop on other teams to gather important information and relay that information to the team.

Outline for Team Reflection:

1. For team to fully achieve their potential, it is important to reflect and think critically about (assess) the effectiveness of their teamwork.
2. Two types of reflection
   - Reflection in action: thinking on our feet
   - Reflection on action: thinking about an experience after it has happened
3. Goal of assessment is to help group members perform better in the future
4. For effective assessment, two things are necessary
   - Trust between the assessor and the assessee
   - Willingness to act on the assessment feedback
5. Based on the results of the assessment, teams can decide if they have met their performance goals and can generate improved plans for future work

Using Activity #6: Team Agreement (Design)

Overview

In this activity, students will develop a team agreement. This agreement should be re-visited as the design project develops and especially at the end as a key to assessing team performance. A good team agreement should give specific details like meetings times and how conflicts will be resolved.

Options for Use

- The preparation of the team agreement can be done either in class or as homework.

Preparing for the Activity

- Review the activity.
- Determine how you want to conduct the activity.

Doing the Activity (Script)

The following script provides ideas for how you would conduct the activity during class.

Slide	Notes
[no slides]	Provide context for this activity, as well as specific instructions and deliverable. Invite students to read the activity. Ask them to discuss what they read with their group and how to integrate what you learned from reading into team agreement. Describe your expectations of a team agreement, how this can be used to monitor team work during the project. Ask them to consider the following questions: • How do you want to be treated by your group? • What do you expect from each group member during a group meeting? • How do you intend to communicate with each other? • How do you intend to keep records of work conducted by the group and by individuals within the group? • How do you intend to resolve disputes or conflicts? • When do you intend to regularly meet outside of normal class hours? • How do you intend to divide work tasks among group members?
	Doing the activity in class: 1. Assign captain, recorder, spokesman. 2. Instructor: review A#6: purpose and deliverable. 3. Process: take 5 minutes to prepare individual answers to CTQ. 4. Group: discuss answers and prepare synthesis and draft document for group agreement. 5. Team: prepare final document that reflects your team perspective, based on group ideas.
	Discussion class after they complete and turn in team agreement: 1. Ask one or two teams to read their agreement. 2. Ask: what is value of agreement? How should you use it during the

Slide	Notes
	semester? How would you assess its value?

Solutions

Example Team Agreement

The following is an example team agreement. Following is an example of a team agreement. It explains exactly when the group will be meeting up, and how group conflicts will be resolved.

We agree to:

- Treat everyone with respect.
- We will work collaboratively on all assignments and activities.
- Every task will be a learning process for each member.
- If one member has confusion on a particular portion of an assignment the other team members will help them understand the process.
- Be prepared and on-time for each meeting.
- Reach decisions by consensus.
- All material collected will be inputted into the computer as soon as possible to have a backup to the raw data collected in the field. The raw data will be kept by the person who collected the data.
- If disputes occur a consensus will be made by the whole group on the issue and hopefully the issue will be resolved. If it is not resolved by the team a peer will be needed that is not biased on the situation to figure out what should be done.
- Disputes should be discussed at the time it is occurring so that the conflict will not get worse.
- We intend to meet Thursdays at 10:30AM to discuss previous tasks and projects as needed.
- Work will be divided equally with the intention that everyone will get a grasp of all the different aspects of a project.
- Everyone should have their task from the previous meeting completed before the next meeting.

<Names>
<Signatures>

Using Activity #7: Introduction to the Traffic Signal Timing Manual (In Practice)

Overview
The purpose of this activity is to become familiar with the Traffic Signal Timing Manual.

Options for Use
- The reading is usually done as homework.
- The synthesis and discussion of the questions can be done as part of a group either during class or as homework.

Preparing for the Activity
- Review the relevant sections of the Traffic Signal Timing Manual.

Doing the Activity (Script)
The following script provides ideas for how you would conduct the activity during class.

Slide	Notes
	• Discuss "In Practice" in general: purpose is to provide a link to what transportation engineers to in practice. Our main link to practice will be the Traffic Signal Timing Manual. It is standard guidebook but is relatively new (3+ years old). New version will be finished next year. • There is a "in my practice" section, a short note from a practitioner. • While the TSTM gives guidelines and "numbers", the more that you know the basics for a guideline, a process, or a number, them more effectively you can answer a design question when you are faced with new conditions or situations.
	• Describe the purpose of the "In Practice" activities and how they will be used to review and calibrate the work that they have previously done in each chapter.
	• Invite them to consider the CTQ and their answers.
	• Ask for answers and discussions for selected questions.

Solution
Answers to Questions
1. What is the purpose of the TSTM?
- The purpose of the TSTM (as stated in the opening page of the manual): "…intended to be a comprehensive guide to the traffic signal timing engineer and technician on traffic signal control logic principles, practices, and procedures." "…represents a synthesis of traffic signal timing concepts, analytical procedures, and applications based on North American practice." It is not "…standards or policy document." "…provides summary of practices intended to help practitioners in the timing of traffic signals."

2. List each of the chapters in the manual and briefly describe the purpose of each chapter. Which of the chapters do you think are most pertinent to the work that you will be doing during this class?

- Chapter 1: Introduction. Provides introductory knowledge on traffic signal systems, some key issues, and the organization of the manual.
- Chapter 2: Signal Timing Policy. Helps define priorities within transportation system. Provides overview of signal timing policies, and signal timing processes.
- Chapter 3: Operation and Safety Analysis. Basic flow principles, capacity and critical movement analysis, performance measures, and safety analysis.
- Chapter 4: Traffic Signal Design Concepts. Phasing, detection.
- Chapter 5: Basic Signal Timing Procedure and Controller Parameters. Lists, defines, and provides best practices for signal timing parameters.
- Chapter 6: Coordination. Presents concepts of coordination, mechanics of coordination, guidelines, transition logic, and complexities.
- Chapter 7: Developing Signal Timing Plans. Scoping, data collection, model development, fine tuning in the field.
- Chapter 8: Signal Timing Maintenance: Operation and Monitoring. Maintenance activities, re-timing, staffing needs.
- Chapter 9: Advanced Signal Timing Concepts. Preemption, priority, traffic responsive, adaptive, weather issues, special events.

3. Which of the chapters do you think are the most pertinent that you will be doing in this class?

- The chapters that are most pertinent: 3, 4, 5, and 6.
- Other relevant chapters and sections include:
  - 1, 2: overview.
  - 3: basic flow principles, CMA, performance measures.
  - 4: phasing, detection.
  - 5: signal timing, controller parameters.
  - 6: coordination.
  - 7: developing signal timing plans.

4. What is the difference between a policy and a standard?

- A policy is a stated goal from a community's vision on how things should be or will be. Or, it is a "a principle or rule to guide decisions and achieve rational outcome." ("what" and "why"). What define a signal timing policy? It should answer the following questions:
  - What should be improved?
  - What objectives or various user needs should be optimized?
  - What performance measures should be tested?
  - What standards must our policy follow?
  - What data should be collected to develop signal timing?
  - What should be measured after implementation?
  - What should be monitored as part of maintenance?

- Other thoughts on policy:
  - Should be extension of regional or local transportation plan (reflect values in safety and operations).
  - Support strategic objectives.
  - How to operate signalized intersections.
  - Prioritize service to travel modes.
- What is a standard? It is a common practice or exemplary. Or, it is “an agreed, repeatable way of doing something.” Source: MUTCD. Examples: safe and consistent pedestrian crossing times, vehicle clearance intervals, signal indications.

5. What defines a signal timing policy?

- Signal timing policy should:
  - What should be improved?
  - Objectives or user needs to be optimized.
  - Performance measures used.
  - Standards to follow.
- Examples:
  - Emphasize bike/ped flows.
  - Transit focused.
  - Emergency vehicle focused.
  - Auto focused.

6. Find the section of the Traffic Signal Timing Manual that deals with the signal timing design process? Target two aspects of the signal timing design process where your understanding could be strengthened. Write a critical thinking question for each of these two aspects. Provide answers to these questions.

- The signal design process is discussed in chapters 1 and 2.

7. What are some of the interesting or important findings of the National Signal Timing study and why do you find them interesting or important?

- Example: Findings of signal timing report card: “many agencies don’t have documented policies.”

8. How does policy support the design of the traffic control system?

- The primary goal of traffic signal timing is to maintain the safe and efficient transfer of right-of-way between conflicting streams of users; however, a safe and efficient system varies within each community’s context as described previously. Thus, local, regional, state, and federal policies must be considered to determine a proper approach. These policies form the foundation from which performance measures are selected. They also provide guidance on (see list on page 10): maximum cycle length, left turn phasing options, transit preference, number of time of day plans.

9. In addition to the examples of signal timing policy application described in your reading of the Traffic Signal Timing Manual, find one other example based on a search of the Internet. Briefly describe it and provide the URL.

- One relevant web site is the Federal Highway Administration's Arterial Management Program. http://ops.fhwa.dot.gov/arterial_mgmt/index.htm

10. What are some advanced traffic control concepts that are described in the Traffic Signal Timing Manual? List and define three of these concepts.

- Some of the advanced concepts include volume/density control, transit signal priority, and railroad preemption.