CHAPTER 6: TIMING PROCESSES ON ONE APPROACH

This chapter includes information that you will need to prepare for, conduct, and assess each of the seven activities included in Chapter 6 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.

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.

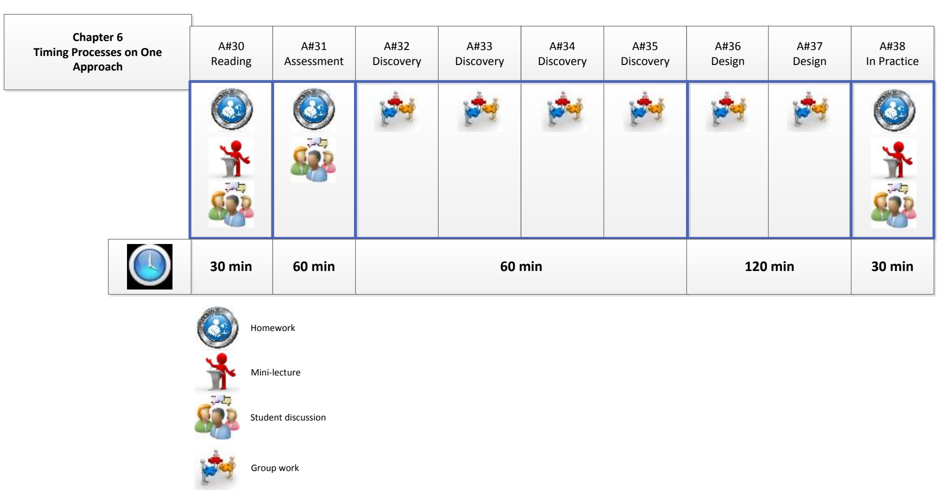


Figure 2. Activity work

Using Activity #30: Considering Minimum Green Time, Passage Time, and Detection Zone Length (Reading)

Overview

Students are asked to complete the reading which introduces them to the relationship between passage time, maximum allowable headway, and unoccupancy time. The reading then presents a stochastic problem to illustrate the relationship and how a signal should ideally terminate, and then explains the problems with real world variation. Queue release characteristics are then discussed. The characteristics are separated into four different groups called segments 1 through 4. The first time segment represents the first few vehicles in queue, these vehicles have lower flow rates and higher headways due to start up. The second segment of vehicles represent the majority of queued vehicles, these vehicles release at the saturation flow rate and have short headways. The third segment represents a transition period between segment two and four, this section is what we hope to detect when selecting a passage time. The fourth section occurs when the queue has been served and vehicles are entering the system at the arrival flow rate.

Options for Use

The reading, defining the terms in the glossary, and answering the critical thinking questions are usually done as homework, to prepare for class discussion. 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.
- Present mini-lecture summarizing key points from the reading, with active questioning of the students as the lecture material is presented.
- Discussion and synthesis of the answers to the quiz, the glossary definitions, and answers to the critical thinking questions.

Preparing for the Activity

- Decide which of the options you want to do during class.
- Prepare for the class by reviewing Activity #30, including the “Information”, the Glossary definitions, and the Critical Thinking Questions and answers.

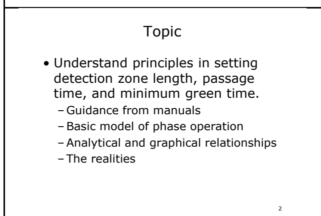
Supplementary Materials

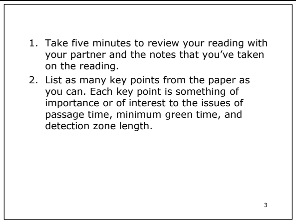
- Slides for class (slides30.pptx)

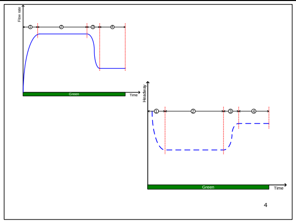
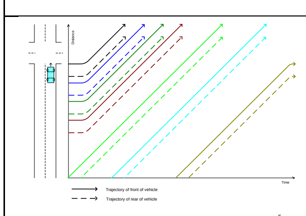
Doing the Activity (Script)

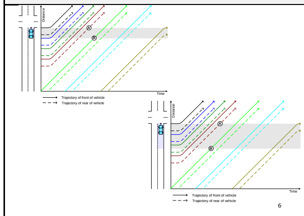
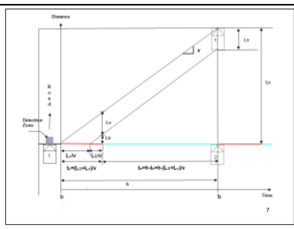
[Slides: slides30.pptx]

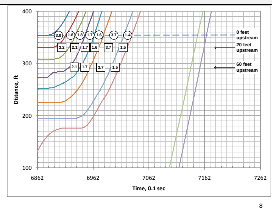
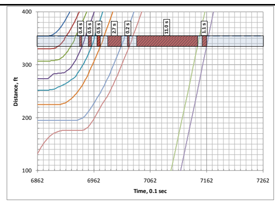
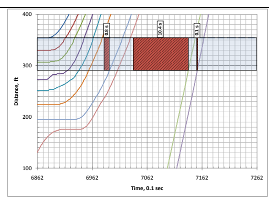
The following script can be used along with the PowerPoint slides for this activity. The script and slides can be modified based on your needs and what you decide to emphasize.

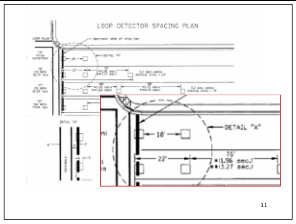
Slide	Notes
	We've talked about timing processes; we'll now discuss how we set the values of the timing parameters that control or set the boundaries for the processes. • Objective: understand basics for setting parameters of detection zone length, passage time, and minimum green time • Basic model of phase operation • Analytical and graphical relationships • The realities: headway distributions, approach speed distributions
	
	Consider the study questions from the reading [refer them to the list in the activity book]: 1. Describe how passage time and the length of the detection zone are related. 2. What is one criterion for terminating a phase? 3. When using a standard loop detector with stop bar presence detection, why is it difficult to determine when a queue has cleared? 4. Explain why the passage time should be decreased when the detection zone length is increased. 5. Explain how variability in the vehicle lengths and speeds affect the determination of the passage time. 6. Describe in your own words the implications of the data presented in Figure 111. 7. Since vehicle headways vary widely and are not constant, even during periods of saturation flow, explain the risks involved in setting the passage time. 8. Summarize your understanding of the headway variability for the four time segments of vehicles departing after the start of green. 9. Describe how the problem of determining passage time changes when considering a two-lane approach.

Slide	Notes
	The purpose of the discussion is to process and enhance what you've read and learned. Questions: we are now going to consider the reading, with some questions to help focus on the key points and how they are linked together. Process that we will follow: 1. Take five minutes to review the reading with your partner and the notes that you've taken on the reading. 2. With your partner, list as many key points from the reading as you can. Each key point is something of importance or of interest to the issues of passage time, minimum green time, and detection zone length. [Report and discuss] [Example list:] 1. Flow profile and segments for departure flow 2. Unoccupancy time – defined 3. Headway, occupancy time, and unoccupancy time 4. Long vs. short detection zones and relationship to unoccupancy time 5. Maximum allowable headway 6. Unoccupancy time defined as a function of headway, detection zone length, vehicle length, and vehicle speed. 7. Effect of stochasticity (headways, driver reactions, vehicle lengths, vehicle speeds) – variability shown in simulation 8. Phase termination criterion: risk management (not too early, not too late)

Slide	Notes
	Look at figure: what is its purpose? What do you learn from this figure? [example answers] 1. There are clear ways to represent the four regimes of traffic flow after the start of green 2. Region 1 is the start of the queue, with some time lost after the beginning of green. 3. Region 2 is the queue clearing at the saturation flow rate. 4. Region 3 is the transition from the queue clearance to the more randomish arrivals and departures. 5. Region 4 is vehicles arriving after the queue has cleared. 6. This figure is important since it defines the time interval that we want to display green (region 1 and 2). More ideas: • Initial queue movement. The purpose is to allow the initial queue (one or more vehicles) to begin to move and safely enter the intersection. This is the initial perception/reaction time to the green display. This requires sufficient minimum green time or sufficient loop length to get the queue started, so that the phase doesn't terminate too early. • Standing queue clearance. The purpose is to provide enough time for the standing queue to clear, and then when the queue has cleared, to terminate the phase so that there is no wasted green time. The phase continues to time as long as the headway between vehicles doesn't exceed the allowable gap (corresponding to a gap that is equivalent to the saturation headway). This requires a trade-off between passage time and detector length. Also important, but maybe less critical, is detector location and minimum green time.
	What did you learn about experiments in which a simulation model is used? These issues will be considered in the design experiments that you will conduct later.
	This slide shows a time space diagram of vehicles arriving at and traveling through an intersection, both the front of the vehicle (solid line) and the rear of each vehicle (dashed line).

Slide	Notes
	What do you learn from this figure? What is its purpose? [example answers] 1. This shows the effect of detection zone length on unoccupancy time. 2. Unoccupancy time depends on length of detection zone, vehicle speed, and vehicle length. 3. The longer the zone length, the shorter the unoccupancy time.
	Why are stochastic impacts important in computing unoccupancy time? • Stochastic variation – there is no set value of headway and vehicle speed.
	So, how do we determine passage time? 1. We determine the maximum headway that we will tolerate. This is usually set based on the observation of vehicle headways during the queue discharge process. We want to make sure that we capture the maximum headway that we are likely to observe during this discharge process. 2. What are the variables that we need to consider. This slide shows the graphical relationship and analytical relationship. Variables defined: v = vehicle speed L_D = detector length L_v = vehicle length h = headway • Time vehicle occupies detector (occupancy time): $$t_o = \frac{L_D + L_v}{v}$$ • Unoccupancy time: $$t_u = h - t_o$$ $$t_u = h - \frac{L_D + L_V}{v}$$ • Implication: if we set the maximum headway that we are willing to accept as h, then the unoccupancy time that we are willing to accept is t_u. • Implication: The passage time should be set equal to t_u. This means that the phase will terminate if the detection zone is unoccupied for t_u seconds, when the headway between the vehicles has reached h.

Slide	Notes
	The realities: headway distribution and speed distribution. 1. During queue discharge process, what is headway distribution? What should maximum allowable headway be set to so that we continue to serve queue? 2. After queue clears, what is the headway distribution? What should MAH be set to so that phase terminates? 3. What is the speed distribution of vehicles during queue discharge process and after queue has cleared? We will investigate these in detail in the lab tomorrow, but let's look at some preliminary data now. This chart shows headways that were measured at three points at an intersection approach.
	This chart shows the unoccupancy times for a 20 foot detection zone at the stop bar.
	This charts shows the unoccupancy times for a 60 foot detection zone also at the stop bar.

Slide	Notes
	Standard Idaho Transportation Department loop spacing plan as example. [addendum from ITD Traffic Manual]: Minimum green: time for one vehicle to move into the intersection from the point of detection. Since ITD uses presence loops located right up to the stop bar, there is no need to provide extra timing for the vehicle to move from the last loop into the intersection. Normal starting delay of the first vehicle in queue is 3.7 seconds. Accordingly, the minimum green should be set to 4.0 seconds. Normal practice = 4.5 seconds. Sometimes add 1-2 seconds for wide intersections. Passage time serves two functions. 1. Sets up amount of gap that will be tolerated between successive vehicles without causing termination of the phase. 2. Provides time for a vehicle traveling at reasonable speed to reach the intersection or the next detector. [once a gap exceeds passage time, the phase will terminate] 3. ITD: multiple loop design. Usually 2.0 sec for most intersections. Loops: see diagram for example timings and settings.

Solutions

The following solutions are included here:

- Glossary definitions
- Critical thinking questions and answers

Glossary Definitions

[From Traffic Signal Timing Manual]

Term	Definition
Call	A term used to describe the presence of vehicle, bicycle, or pedestrian demand in an actuated detection controller system.
Detection zone	The area in which vehicles will be detected on an intersection approach.
Interval	The duration of time where a traffic signal indication does not change state (red, yellow or green). traffic signal controller also has timing intervals (min green, passage time) that determine the length of the green interval.
Maximum allowable	The maximum time separation between vehicle calls on an approach without gapping out the phase, typically defined by passage time or gap time. Maximum allowable headway refers to spacing between common points of vehicles in a

headway	single lane, but the term is commonly used to refer to maximum time separation in single or multi-lane approaches as well.
Occupancy time	The time when a detector is occupied.
Recall	A call placed for a specified phase each time the controller is servicing a conflicting phase. Recall is used to endure that the specified phase will be served again.
Unoccupancy time	The time which the detector is unoccupied
H	headway
Ld	detector length
Lv	vehicle length
To	occupancy time
Tu	unoccupancy time
v	vehicle speed

Answers to Critical Thinking Questions:

1. Describe how passage time and the length of the detection zone are related.
- As detection zone increases passage time decreases.

2. What is one criterion for terminating a phase?
- One criterion for good signal terminations is when the signal terminates after the queue clears.

3. When using a standard loop detector with stop bar presence detection, why is it difficult to determine when a queue has cleared?
- The detector is only able to output if the detector is on or off. The detector must be off for long enough to reasonably assume that the queue has cleared; unfortunately different driver behaviors become an important component making the process difficult.

4. Explain why the passage time should be decreased when the detection zone length is increased.
- Headways are calculated from front of vehicle to front of vehicle, meaning that no consideration is made for the length of the vehicle. It is also more effective to have a large detector length to help ensure the driver drives over the detector. These two factors explain why the passage time should be decreased when the detection zone length is increased.

5. Explain how variability in the vehicle lengths and speeds affect the determination of the passage time.
- If the approach speed is high then the passage time will be higher.
- When the vehicle length is high the passage time will be smaller.

6. Describe in your own words the implications of the data presented in Figure 111
- These charts show the theoretical headway and flow profiles as the queue begins to move and clears after the beginning of green. Superimposed over these theoretical profiles are example simulation data showing the kind of variation that we would observe in the field. One of the implications is that there is often a large variability in vehicle headways, varying around the theoretical values. This makes it challenging to specify a target MAH that works perfectively in all situations.

7. Since vehicle headways vary widely and are not constant, even during periods of saturation flow, explain the risks involved in setting the passage time.
- Two potential problems emerge when setting the passage time. The passage time could be set too short or too long. If the passage time is set too short, the signal will change before the queue is served causing a cycle failure. When the passage time is set too long, the signal may extend excessively and phasing out due to max-outs.

8. Summarize your understanding of the headway variability for the four time segments of vehicles departing after the start of green.
- As the queue is clearing, the variability of the headways around the theoretical saturation headway is much smaller than the variation that is observed for the four time segment, where variability around the mean flow rate or headway can be quite high.

9. Describe how the problem of determining passage time changes when considering a two-lane approach.
- Often on a two lane approach we only know that a call has come for an approach and not the specific lane on the approach. This means that the observed headways can be quite small, since vehicles from both lanes are contributing to the observed "approach headway".
  - Another thought: approach detection is almost always more inefficient that lane by lane detection, since you could see a headway of twice the MAH (if we were looking at headways in each lane) and still continue to time the phase. Unfortunately, even though this is true, many signalized intersections still use approach detection.

Other Notes

Learning What Students Understand and Don't Understand

What follows is a series of student questions and answers that are helpful in reviewing potential issues that arise from this exercise.

The following questions and my responses from previous versions of the course are listed below. Their responses are in answer to the question: "After the discussion in class today, what topics did you still not understand?" Their responses provide some perspective for future instructors on the kinds of reactions from students.

1. We didn't quite grasp whether the passage time should be increased or decreased when the detection zone was increased.

- We'll discuss more tomorrow in the lab exercises. The longer the zone, the shorter the needed passage time.

2. What exactly does the "departure headway profile" graph illustrate?
- The headways of vehicles as they depart from the stop bar.

3. I was a little confused when I was calculation the vehicle clearance time for the lab, should this be evaluated over a range of speeds or just the one that we found?
- The vehicle clearance time that you select has to be one number. The reason for looking at the range of speeds is to understand the sensitivity of the calculation to speed.

4. If the passage time and detection zone length are adequate, is a minimum green time still necessary?
- Yes because, regardless of the initial queue, you will need to have a minimum green time to meet driver expectancy.

5. The question we had was regarding the passage timer set to zero if the length of the detection zone is equal to the space headway between successive vehicles discharging at saturation flow. This seemed like a very small detection zone, thus seeming insufficient. We would like some clarification on that.
- We will look at the relationship between headway, unoccupancy time, and passage time in the lab tomorrow.

6. What kinds of things can we do to better understand the relationship between min green time and driver expectation?
- This is an example of research that is necessary; it involves human factors, specifically how drivers perceive various timing intervals.

7. What is the max detection length for an intersection?
- There is no maximum value. However, typically in practice, left turn lane detection might be as long as 80 to 90 feet. Stop bar loops are typically 22 feet in Idaho; other states sometimes have lengths of 40 feet or more.

8. Is there an easy way to evaluate data and know when vehicles begin to respond to yellow? It seemed arbitrary for some of the vehicles.
- The speed that a driver selects is the only measure that we have, short of being in the car with the driver.

9. How often in practice is passage time set to zero?
- Not very often, though very short passage times are being considered in some jurisdictions.

10. We are not fully sure how to interpret the departure flow rate and departure headway graphs.

- They are simply plots of the flow rate and headways as measured at the stop bar, as vehicles leave the approach and enter the intersection.

11. Why would it not be valuable to always make your detection zone long enough to set your passage time to 0?
- Longer detection zones cost more.

12. Is it preferable to have a zero-length passage time?
- No. It depends on the length of the detection zone. There are however arguments for making passage times shorter than often used in practice. More to say on this in the lab tomorrow.

13. What is detector length that would use a zero second passage time?
- A detection zone of 60 feet makes a zero second passage time possible.

14. I don't really understand why you only want to serve the queue of one phase and then switch right away to the next one. It makes sense if there is no one else coming, but if there are still more cars coming that weren't part of the queue, don't you want to serve them too?
- At most intersections, there is a continuing demand on at least two phases (if not more). It is most efficient to complete service to one phase and then to move on to the next (thus minimizing delay for all movements). The optimum time to end service to one phase is when the standing queue has cleared since after the queue has cleared the headways between vehicles can become quite long (making vehicles on the other approaches wait an inordinate amount of time).

15. Why does the vehicle change interval seem to be not as important as vehicle clearance interval?
- In most cases, these terms mean the same thing.

16. How would placement of detector and if multiple detectors were installed relate to increasing the detection zone.

17. With a fully actuated system and a sizeable detection zone, is it more efficient to run with zero green time so that phases can terminate at any given time?
- With a long enough detection zone, you can have both zero minimum green time and a zero passage time. For a short queue, however, a long zone will cause the phase to extend too long.

18. What is a common detector length that has a passage time of 0 seconds?
- As noted in #2 above, a 60 foot zone make a passage time of zero possible. However, in practice, a zero passage time is rarely used. Most agencies want to have a more

conservative approach to make sure that all vehicles in the queue are served, even if it means a less efficient operation.

19. I'm sure it is somewhat subjective and up to an engineer's judgment, but how is the detection zone length and passage time determined?
- The detection zone length is usually determined first, based on the approach speed. The passage time is determined after the zone length (and placement) is determined.

20. What did the L variables stand for in the equations written on the board?
- L is the vehicle length.

21. I do not completely understand what every term in the equation written on the board means. I'm assuming I'll have a better understanding after tomorrow's lab.
- See notes from today's class for a complete list.

22. Does L.D and L.V stand for?
- LD is the detection zone length; LV is the vehicle length.

23. Is it common to set the passage time to zero?
- No. Most agencies don't have zone lengths that are long enough to accommodate a zero value for passage time.

24. Why can the passage time be set to zero when the length of the detector is increased?
- Look at the equation and chart presented in class (and included in the notes) to get a better understanding of the relationship between these two parameters.

Student Reflections on Reading: "Was This Reading Helpful to You?"

The following questions and my responses from previous versions of the course are listed below. Their responses are in answer to the question: "Was this reading helpful to you?" While most students answered "yes" to this question, their responses provide some perspective for future instructors on the kinds of reactions from students.

- Going through it with a partner doesn't really help, but when you go through it and tell us what you think are the important parts is helpful.
- Yes, I think the review helps a lot to better understanding of the readings.
- I thought the quick review was very helpful because one might read the assigned reading and never really have a grasp on what was going on. Reviewing it allows the information to sink in.
- I do like the open discussions about the reading material, it is helpful to hear other students' points of view to really get a grasp on the details of the major concepts, especially since intersections are such complicated machines!
- The review of this reading was helpful because it gave me another person's point of view at the topics and can possibly lead to something that has been overlooked.
- I thought it was helpful because often after I read something once, I may not get all of the points but a review helps.
- I think this sort of review is much more helpful than quizzes over the reading because this way if I didn't pick

up on something I was able to talk to a partner about it and discussion is the easiest way for me to retain knowledge.

- The review of the reading was helpful because it went over the key points that you wanted us to get out of it. It provided a more focused look at the material that was contained.
- I thought the detailed review of this particular reading assignment was valuable and important because it helped solidify the concept of passage time and how it relates to vehicle detection.
- The only minor improvement I can think of relating to today's lecture would be a slight increased focus on graphically demonstrating the concept of passage time.
- I think a detailed review of the reading is very helpful. I think it helps separate the important things from the extra information that is not necessarily important. It also helps to realize what the teacher is choosing as important from the reading and keeps everyone on the same page. I am not too sure how it could be improved but I compare it to reading a novel, then going to listen to the author talk about the novel. To fully understand it you need to understand what the writer was thinking when they wrote it and after all if they wrote it they should be the best person to separate the important information and also explain it the best.
- The detailed review of reading as given in the yesterday's class was quite useful for today's class participation. It helps to catch up the detailed discussions made on the class and also to clear up if there is any confusion left for the readings. So far it is ok form the process point of view.
- I think the detailed review of the reading was very helpful. It's hard to find time on top of all the class and lab homework as well as work from other classes to do the readings before every class. This reading was helpful because of the study questions and reading out the aspects we felt were important to one another out loud. I think this process could be improved if we simply did it more often in class.
- Detailed review IS helpful. Reading can often be very technical and difficult to comprehend. Reviewing allows a second analysis of it, as well has others' understanding and your own.
- Detailed review of the readings is helpful to understand the relationship between detection zone and passage time and also to interpret this with flow rate and headway.
- Yes, the reading section is helpful. Because this clears the idea about the passage time, MAH, headway. This part can be improved by adding more parameters in the reading part.
- Yes it was helpful. It made it easier to understand what the reading is trying to get across by putting it in easier terms and discussing it. I think the process is good.
- Personally I feel it would be better to have 3 or 4 questions as a homework over the reading, this helps because I then remember I need to read it and I read it and the questions help us to focus on what you would like us to learn from it...

Comments from Students

The following comments were made by students after the completion of the Activity #30 discussion, including the main things that they learned.

- Passage time is dependent on the length of the detection zone
- Phase will terminate when unoccupancy time is equal to the passage time
- Max allowable headway is what passage time is derived from
- Relation between the length of the detector and the amount of time set for the passage timer
- Variability in the drivers decisions makes it difficult to find an exact MAH which makes finding passage time difficult as well
- With two lane approaches the controller see's the lanes as a combination, which results in a vehicles from lane one or lane two resetting the passage timer. This results in shorter unoccupancy times and shorter corresponding passage times and headways.
- Shape and meaning of each portion of headway/vehicle position curve and flow rate/vehicle position curve
- Effect of random driver behavior on both of these curves after queue clearance
- Equations for headway
- The effect of one detector for multiple lanes on apparent headway (the headway as seen by the detector) and the need to adjust passage time accordingly

- Shift in density functions to the right for 1-lane flow data relative to 2-lane flow data
- The passage time/detector length relationship; greater detector length = lower required passage time
- Passage time
- It's hard for a loop to perform with multiple lanes because it has a hard time determining where the cars actually are, so the passage time can be off.
- The longer the detection zone the shorter the passage time.
- HCM suggests an ideal value of 1900 vehicles per hour of green for the saturation flow rate.
- After queue has cleared, the passage time becomes random, so it's hard to know when the queue has cleared.
- Public complaints are taken into account when setting minimum green time.
- As detector length increases the passage time will decrease.
- Maximum allowable headway is controlled by detector length.
- Developing MAH is a balance of two risks.
- Longer detection zones require shorter passage times.
- With multiple lanes passage time needs to be shorter due to the headways from both lanes being seen as from one lane only.
- With long detection zones and large passage times, the max green is likely to be used every cycle. This leads to longer delays in other approach lanes.
- The ideal length of green is to serve the current queue and clear the queue and end once this has happened. However with large passage times or long detection zones, headways can be larger after the queue has cleared and the phase will not gap out as it is supposed to.
- The detection zone length determined the passage time because the time required to pass through the detection zone is longer as its length increases and shorter as its length decreases. This directly affects the unoccupancy time – which is supposed to represent the passage time.
- We noticed that even after the queue has cleared and the saturation headway has reached its actual headway there are still vehicles that can arrive at the saturation headway. This will prevent the passage timer to expire as the vehicles do not reach MAH

Using Activity #31: What Do You Know About Detection Zone Length and Passage Time (Assessment)

Overview
The purpose of Activity #31 is to assess how well the student understood the reading from Activity #30 and how well they are able to apply its key concepts in several applications.

Options for Use
- Completion of tasks as homework.
- Completion of tasks during class.
- Hybrid: completions of tasks 1 and 2 (setting up the spreadsheet tool) as homework and use of the spreadsheet tool (tasks 3 and 4) during class.

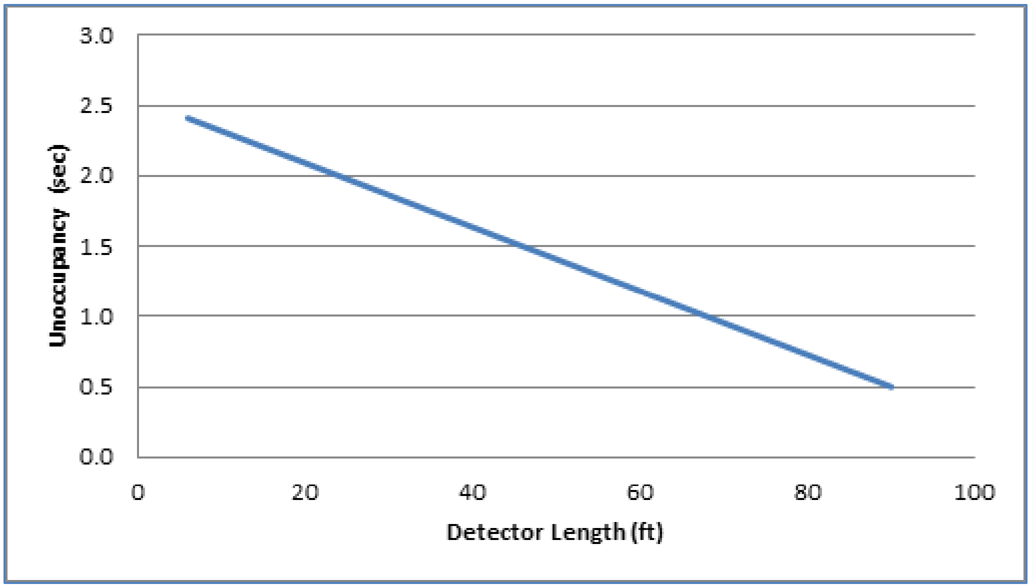
Preparing for the Activity
- Confirm options for class period.
- Review the critical thinking questions and answers.
- Review spreadsheet tool and the answers to tasks 1 through 4.

Doing the Activity (Script)
1. Invite the students to read through the activity. Review the learning objectives, the deliverables, and the tasks.
2. After they complete the tasks, review their results, discussing some of the key points that they learned.

Solutions
[Solutions and answers to tasks: solution31.xlsx]

Included here includes:
- Critical thinking questions and answers
- Issues from student responses
- Other student notes and questions

Critical Thinking Questions and Answers
1. What is the relationship (in equation form) between unoccupancy time and maximum allowable headway (MAH)? What are some of the issues involving the computation of the unoccupancy time for a given intersection approach? Provide your answer in a complete paragraph.
- This figure shows the relationship between unoccupancy and detector length for a MAH of 3 seconds, a vehicle length of 20 feet, and a vehicle speed of 30 mph.



2. What is the process for setting the passage time, given the MAH? Describe in complete sentences.

- Determine the maximum headway that you are willing to tolerate before the phase terminates.

3. What are the pros and cons of a detection zone that is 100 feet in length? Provide your answer in one or more complete paragraphs.

- Pros:
  - Easy to ensure vehicle is detected
- Cons
  - Passage time calculations could be in the negatives
  - Longer detector is more expensive
  - Longer detector is more likely to break

4. How would the determination of the MAH change if you considered lane by lane detection for a two-lane approach (that is, detectors in each lane, operating independently)?

- For approach detection, the call is held active regardless from which lane the call is received. That is, the phase will continue to time as long as a call is active from a vehicle in either lane. This can generate in the worst case, headways between vehicles in the same lane as long as twice the maximum allowable headway. For lane by lane detection, the passage timer is maintained for each lane and each timer times independently of the other. Lane by lane detection can thus be more efficient than approach detection. The passage timer is thus set lower for approach detection to account for this potential inefficiency.

Issues from student responses last year

1. Are they using lane by lane detection or approach detection?
2. Note that they are building tool and data for the completion of the first design.
3. Be clearer with the knowledge base; show them what they've learned, both for design report and for exam.
4. Add to lab description: what they should be prepared to bring to class.
5. Change case 5 values of PT and MG (?)
6. Closing activities: two things that you learned today and one question that you have on today's assignment and lab.

Student Notes and Questions from Past Classes

1. For case 4, our SB green phase did not always terminate after the 1 second passage time or the 1 second min time. What would cause this?

- Could be several things, including detectors not connected to the correct phase; let's review this in lab.

2. One of the notes for a_19 says that VISSIM can auto record the green times. What do you need to do to be able to do this?

- Check the VISSIM help file for all of the details: (1) the LZV files records the green time distribution for all phases ("Distribution of green times" in evaluation window) and (2) the LDP file record phase durations.

3. Is there a standard for too much/too little passage time length for a given speed?

- See the table in chapter 5 of the Traffic Signal Timing Manual (page 21).

4. What is the best measure for deciding the efficiency of the intersection (detector length, passage time, and minimum green)? What determines which case is better?

- Several measures are used (not just one): green time duration, utilization of green, unused green time.

5. Are there state standards on minimum green time length or are they more of an engineering judgment?

- Most jurisdictions have a manual with suggested or required values of timing parameters. See, for example, section 300 of the Idaho Transportation Department manual.

6. Is it possible to have the same results for a small detection zone with a large passage time compared to a large detection zone with a small passage time?

- Yes.

7. For task 4 case 5 is it fine to use 5 second and 10 second minimum green times for left turn and through lanes respectively?

- Yes, if that is what you decide based on your analysis.

8. In task 3, to calculate unoccupancy time, we are using mean headway and 85th percentile headway for the two cases. I think we are using mean in the first case because, the headway between vehicles in the standing queue are more uniform than vehicles arriving after the green?

- Both of these cases are intended to show the variation that can result depending on your assumed input values.

9. If there is a fairly large variability within the unoccupancy times for assignment 5, should we choose a passage time that relates more closely to the majority value of the unoccupancy times?

- I would use something closer to 85th percentile. You could also show me your results and we can discuss.

10. What kind of statistical tool could we use to determine the interval of velocities in order to get the cumulative distribution?

- See discussion at the bottom of this page.

11. What range of detector lengths are used in the industry? (What's too short or too long from a practical standpoint?)

- The range is from 6x6 loops to 6x50-100 feet.

12. I'm still unclear about the unoccupancy time and how it relates to the dilemma zone.

- These two parameters are not related.

13. Once the unoccupancy time has been determined what is the common practice on choosing a passage time... more? less? close to the same?

- The passage time is set equal to the unoccupancy time.

14. Are there state standards on minimum green time length or are they more of an engineering judgment?

- Most agencies have standards for minimum green time and passage time, as well as a set of detector standards (usually based on approach speed).

15. What is the average length of a detector if the passage time is set to zero?

- Look at the results of Assignment 6.

16. Should the calculated value of the 85th percentile unoccupancy time be used directly as the passage length?

- This would be acceptable.

17. My question is how one goes about justifying passage time? By this I mean how do you know a time is adequate for your intersection.

- Follow the three steps I outlined in class today: Determine maximum acceptable headway, compute unoccupancy time, set passage time equal to unoccupancy time.

18. Is it more effective to have a longer detection zone with a shorter passage time than it is to have a longer passage time with a shorter detection length?

- From a purely operations perspective, both are equivalent. Cost often argues for shorter loops.

19. When you calculate tu, you get a value with too many decimals, do you want to round that number up all the time, down all the time, or just using regular rounding rules to find your PT?

- Passage time should be set to the nearest 0.1 second.

20. Is it correct to assume a passage time that is equal to the total unoccupied time? This is relating to homework number 5.

- Yes.

21. When determining the passage times from the unoccupancy time do you need to round to the nearest whole number or can it be set to the tenth of a second?

- 0.1 second precision.

Students Questions:

- What is a good passage time when having a detection zone of 20 feet?
- Passage time to detection zone relationship
- How is maximum allowable headway used to determine an acceptable passage time?
- The concept that I'm still confused about is maximum headway.
- How common is recall use in intersections?
- I am still confused about the different types of recall.
- If we use 2 6 ft detectors to make a 22 foot loop, why not just use one detector further up the lane and use an increased passage time?
- How to determine the correct passage time and detector lengths since headway varies?
- Still don't know what is going on with flow rate vs. time and headway vs. time graphs.
- I still don't feel very confident in my understanding of "recall" and how it applies.
- I am confused about the 3rd question on Activity 20 task 2, how the loop detector stop bar detection will be difficult to determine the queue length.
- I still do not fully understand the equation and graph on pg. 129
- I am not sure why it would be difficult to measure the queue in a closed loop detector
- I want to learn more about the recall.
- I still don't understand what the purpose of recall is.
- What is the difference between passage timer and passage time?
- Can they test loop detector placement in the field before implementation?

Using Activity #32: Relating the Length of the Detection Zone to the Duration of the Green Indication (Discovery)

Overview
Activity #32 expands student understanding of the actuated control timing processes and building the signal timing design by determining the values of the minimum green time, the vehicle extension time, and the length of the detection zone.

The purpose of this activity is to learn how the detection zone length affects the operation of a phase. In this activity, students consider two cases, one in which the southbound approach has a 22 foot detection zone and another in which the southbound approach has a 66 foot detection zone, each representing a zone length sometimes used in practice. In both cases, the detection zones end at the stop bar.

By the end of the activity, students should be able to articulate how changing the detection zone length will affect the performance of the intersection when all other variables are kept constant. Specifically, students should observe that for the 22 foot detection zone, the phase gaps out before serving all of the queued vehicles, while for the 66 foot detection zone, all of the vehicles are served. This should reinforce students' knowledge of the relationship between detection zone length and passage time.

Options for Use
- Activity #32 can be conducted as part of a sequence of four activities, Activities 32 through 35. In each of these four activities, students learn more about the relationship between the minimum green time, the vehicle extension time, and the length of the detection zone.]
- The sequence of four activities can be conducted either in class or as homework.

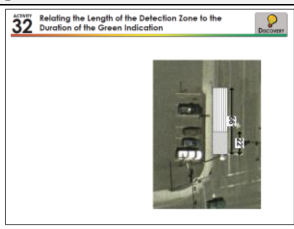
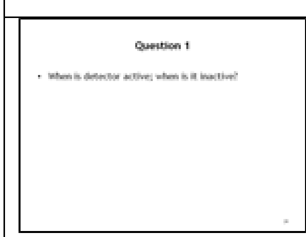
Preparing for the Activity
Watch the video before class.
- Two side by side views of identical intersections are shown.
- The focus is on the southbound approach, which is controlled by phase 4.
- The traffic volumes on the southbound approach are the same, five vehicles in queue at the start of green.
- The timing parameters are:
  - Minimum green time = 0 seconds
  - Vehicle extension time = 0 seconds
  - Maximum green time = 50 seconds
- The only difference between the two views is the length of the detection zone on the southbound approach. The zone in the left view is 22 feet long while the zone in the right view is 66 feet long.

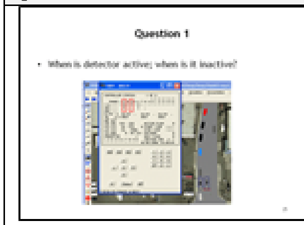
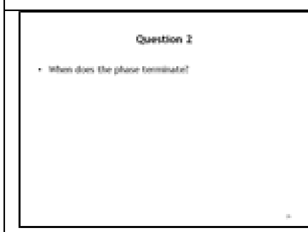
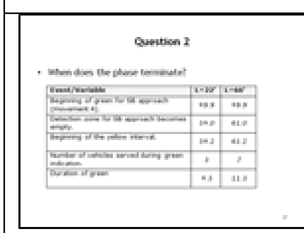
The key point is effect of the detection zone length on the duration of the green. Since the Vehicle Extension Time has been set to zero, the phase will terminate immediately when the call is dropped (and the zone is not occupied by a vehicle). This happens in the left view when the second vehicle leaves the zone. In the right view, since it is longer and more vehicles can be in the zone at the same time, the call is active when the first six vehicles travel through the intersection. The detection zone, in the view on the right, serves some of the same function as a non-zero Vehicle Extension Time.]

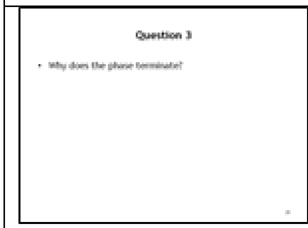
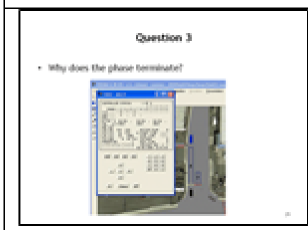
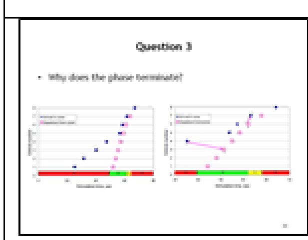
Following is a script that you can review as you watch the supplemental video for Activity #32 to get a better feel for its content:

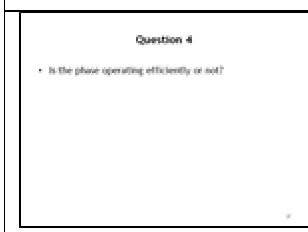
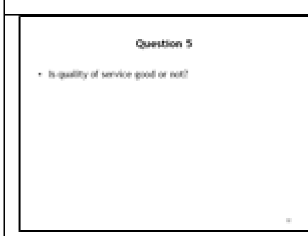
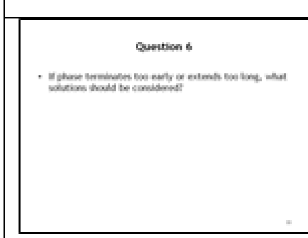
Video (sec)	Script
0:0	The video for Activity #32 shows two cases, aerial views of two intersections, side by side. The geometry of both intersections is the same. The detection zones are different, however. In the left window, the zone is 22 feet long while in the right window the zone is 66 feet long.
0:15	The simulation clock reads 47.6 seconds. Phases 2 and 6, serving the eastbound and westbound traffic, have just gapped out and the signal display for these phases is yellow.
0:26	Our focus is on the southbound approach, phase 4. The display for this phase is currently red. Four vehicles are stopped on the southbound approach and two vehicles are about to enter the queue. The Controller Status display shows a “N” for phase 4, indicating that phase 4 will time next, after phases 2 and 6 have terminated.
0:43	The Vehicle Extension times and the Minimum Green times for phase 4 have been set to zero for both cases. Since these timers have been set to zero, the length of the detection zone alone will determine the duration of the phase 4 green display.
0:57	The phase 4 display turns green. Since there is a call on phase 6, the maximum green timer begins to time.
1:04	On the left, the second vehicle in the queue leaves the detection zone before the third vehicle enters. The vehicle extension timer immediately expires, as its initial value was set to zero. Phase 4 gaps out.
1:14	On the right, with the 66 foot detector, there is still at least one vehicle in the zone and phase 4 continues to time.
1:22	But there is now a long enough gap between the vehicle in the zone and the next one that even with the longer zone, the call is dropped and the phase gaps out. Yellow, and then red, is displayed for phase 4.

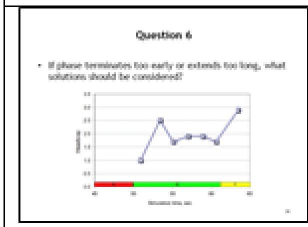
Doing the Activity (Script)
[Slides: slides32.pptx]
You can use all or part of the following script, along with the slides, to guide the activity.

[Slides:	**Script**
 	**Key Message:** Introduction to Activity #32, the Effect of Detection Zone Length on Green Duration. **Background Information:** The learning outcome for this lesson: • Be able to relate the length of the detection zone to the duration of the green indication. **Interactivity:** **Tell:** Activity #32 list the learning outcome for this experiment, an overview of the experiment, the questions that you will answer once you've finished the experiment, and the list of steps that you will complete during the experiment. Take about two minutes to read the activity. [Once they have completed reading the activity] **Ask:** Do you have any questions on this material? **Tell:** Emphasize the learning outcome for this lesson. Be able to relate the length of the detection zone to the duration of the green indication **Notes:** It is important that the students remember that the "Critical Thinking Questions" should be kept in mind during the activity and will serve as the basis for the discussion that will take place when they have completed the tasks. In this activity, two different detector lengths are used, 22 and 66 feet. Give the students about 5 minutes to complete their observations and answers.
 	**Key Message:** Consider question 1 and encourage the students to think about it and their answer. **Interactivity:** **Tell:** Let's now discuss the questions that were asked at the beginning of this lesson. **Ask**: When is the detector active and when is it inactive?

[Slides:	Script
	**Key Message:** This slide highlights several parts of the control display screen that relate to the status of detector calls and the timing process. **Background Information:** "T" is for the phase that is timing. "N" is for the next phase will be timing. "C" means there is an active call. **Interactivity:** **Answer:** This chart shows the controller status window, with the detector status data highlighted with the red boxes for phases 2 and 4. Here, phase 4 (the SB approach) has no active call (as indicated by the "." in the controller status window). This is confirmed by looking at the SB approach where no vehicles are in the detection zone. While you can't see the EB approach, you will note that there is an active call on phase 2 (as indicated by the "C" in the controller status window).
	**Key Message:** Consider question 2 and encourage the students to think about it and their answer. **Interactivity:** **Ask:** When does the phase terminate for the SB direction for each of the two scenarios? **Notes:** Relevant information is provided on the next slide.
	**Key Message:** This slide highlights the data that were collected during the experiment. **Interactivity:** **Tell:** Table 2 shows data that were collected for the period when each of the phases terminated. Study these data for a moment. **Ask:** When does the phase terminate for the SB direction for each of the two scenarios? **Answer:** From the table, you can see that phase 4 terminates at t = 54.2 seconds for the 22 foot detection zone scenario and at t = 61.2 seconds for the 66 foot scenario. **Ask:** what do the data in this table tell you about how the detection zone length affects the duration of green? **Answers:** The 66 foot detection zone had a longer green duration. The longer zone accommodated more than one vehicle at a time and thus kept the call active on phase 4 for a longer time than the shorter

[Slides:	Script
	detection zone. This enabled twice as many vehicles to be served during this green interval.
	**Key Message:** Consider question 3 and encourage the students to think about it and consider their answer. **Interactivity:** **Ask:** Why does the phase terminate for each of the two cases? **Notes:** Give them a minute or so to consider their answer and then ask for possible answers. Answers are provided on the next page.
	**Key Message:** It is important that the students consider these questions and their answers; this is what helps deepen their learning process. **Background Information:** Unoccupancy time is the time that a detection zone is unoccupied, measured from the downstream departure of the rear end of one vehicle to the upstream arrival of the front end of the following vehicle in the detection zone. It is also referred to as "gap time." **Interactivity:** **Answer:** For both cases, the phase terminates because the unoccupancy time exceeds the value set for the Vehicle Extension time. In this experiment, the Vehicle Extension time is set to zero, so the phase terminates immediately after the detection zone becomes empty. This slide shows the status of the 66 foot detection zone case at t = 61.2. The black vehicle has just exited from the detection zone and the blue vehicle has not yet entered the zone. When the zone becomes empty, the call is dropped (note the "." in the controller status window for phase 4), the green indication immediately terminates for the SB approach, and the yellow timer has begins timing. Finally, the status for phase 4 shows "gap out," indicating that the phase is terminating because the unoccupancy time (the time that the detection is unoccupied) exceeds the value set for the Vehicle Extension time. In this example, the blue vehicle enters the intersection on yellow and clears before the conflicting phase begins.
	**Key Message:** It is important that the students consider these questions and their answers; this is what helps deepen their learning process. **Interactivity:** **Tell:** You can graphically show the interaction of the vehicles arriving and leaving the detection zone with the status of the phase. The two figures illustrate the 66 foot detection zone case. The chart on the left

[Slides:	**Script**
	shows the times that each vehicle enters into (diamond) and departs from (square) the detection zone. The chart on the right contrasts the times that one vehicle leaves the zone and the following vehicle enters the zone, zooming in for the time period that the green indication is active. For example, vehicle 4 enters the zone before vehicle 3 exits the zone, so that the zone is continuously occupied and the unoccupancy time is zero. The arrow emphasizes that the arrival of vehicle 4 into the zone occurs before the departure of vehicle 3 from the zone. By contrast, vehicle 6 exits the detection zone at t = 61.0, 0.6 seconds before vehicle 7 enters the zone. The unoccupancy time is thus 0.6 seconds, and since the Vehicle Extension time has been set to zero, the phase will terminate at this point. And, this is exactly what you observed in the animation. Here, the arrow notes that vehicle 6 departs from the zone before vehicle 7 arrives in the zone.
	**Key Message:** Consider question 4 and encourage students to think carefully about both the question and their answer. The length of the detection zone does matter; it is one of the factors that affect green duration and efficiency. **Interactivity:** **Ask:** Is the phase operating efficiently or not for the two scenarios? **Answer:** The short detection zone does not reasonably serve all the vehicles in the queue. The longer detection zone provides more efficient service by clearing the last vehicle during the yellow.
	**Key Message:** Encourage the students to consider this question and their answers to it. **Interactivity:** **Ask: Is quality of service good or bad?** **Answer:** Only the longer zone provides efficient operation, while the 22 foot zone scenario “gaps out” too early. This is because there are still vehicles in the queue that should be served but were not.
	**Key Message:** Encourage the students to consider this question and their answers to it. **Interactivity:** **Ask:** If the phase terminates too early or extends too long, what solutions should be considered?

[Slides:	Script
	Notes: The responses are provided on the next page.
	**Key Message:** Encourage student discussion of this answer. **Interactivity:** **Answer:** Our goal is to make sure that the queue that is present at the beginning of green is served and that the phase does not terminate too early (before the queue ends) or extend too long (after the queue has been served). The detection zone itself cannot do this alone. You also need to consider the Minimum Green time and the Vehicle Extension time, and the value that they bring to the operation of the intersection. This point can be illustrated by graph in the slide which shows the headways as measured at the stop bar for each of the first seven vehicles in the queue, for the 66 foot detection zone case. These headways vary about the ideal saturation headway value of 1.9 seconds, something that you would expect to see in the field as a result of the differences in driver behavior and reactions. This point is illustrated by the seventh vehicle in the queue which has a longer headway (2.9 seconds) and faces a yellow indication because the unoccupancy time is greater than zero. In this case, the vehicle was too close to the intersection to stop and entered on yellow. In the following Lessons, you will see how the Minimum Green time and the Vehicle Extension time can be used to maintain efficient operations and improve the quality of service to the motorist, in combination with the detection zone length.

Solutions

Included:

- Answers to questions in tasks
- Critical thinking questions and answers

Answers to questions in tasks

Task 3: Observe the simulation at t = 49.9. Record your observations on the status of phase 4. What is the color of the active indication?

- At t=49.9, phase 4 is the active phase for both cases. Additionally, both cases have four vehicles in the active queue with several more vehicles approaching the intersection. Because vehicles are in the detection zone for each case, there is a call shown in the vehicle call section of the controller screen. Finally, in both cases, the color of the active indication is green.

Task 4: Observe the simulation from t = 54.1 to 54.3.

- Observe the simulation on the left of the screen (the 22 foot detector case).
- Record your observations of the controller status window in the box at right, noting in particular the status of any calls, the timing status of phase 4, and the timing processes and timing parameter values for phase 4.
  - At t=54.1, the detector becomes unoccupied. Because the vehicle extension time is set to zero seconds, when the detector is unoccupied, the phase terminates even though there are several vehicles still waiting to be served.
- Also, record the status of the queue being served.
  - When the green phase terminates, five queued vehicles have yet to be served. One of these vehicles enters the intersection during the yellow indication, leaving four unserved vehicles.

Task 5: Observe the simulation from t = 60.1 to 61.4.

- Observe the simulation on the right of the screen (the 66 foot detector case).
- Record your observations of the controller status window, noting in particular the status of any calls, the timing status of phase 4, and the timing processes and timing parameter values for phase 4.
  - At t=61.3, the detector becomes unoccupied. Because the vehicle extension time is set to zero seconds, when the detector becomes unoccupied, the phase terminates.
- Also, record the status of the queue being served.
  - All of the queued vehicles are served before the phase terminates.

Answers to Critical Thinking Questions

1. When is the detector active and when is it inactive?
- The detector is active anytime that a vehicle is in the detection zone. As soon as there is no longer a vehicle in the detection zone, the detector becomes inactive.

2. When does the phase terminate for the SB direction for each of the two cases?
- The 22 foot case terminates at t=54.1, the 66 foot case terminates at t=61.3.

3. Why does the phase terminate for each of the two cases?
- The SB phase terminates due to gap out as soon as the detector us unoccupied.

4. Do you think that the phase is operating efficiently or not for the two cases?
- The 22 foot case is operating inefficiently because four queued vehicles are not served. However, the 66 foot case serves all of the queued vehicles before terminating, so it is operating efficiently.

5. Do you think that the quality of service provided to the motorist is good or not?
- Because approximately half of the queued vehicles are not served in the 22 foot case, motorists are receiving a poor quality of service. However, the quality of service in the 66

foot case is good because all of the queued vehicles are served before the phase terminates.

6. If the phase terminates too early or extends too long, what solutions should be considered?

- If the phase terminates too early, increasing the passage time or the detector length should be considered. Doing this would allow for more time between when one vehicle exits the detection zone and the next vehicle enters the detection zone, lowering the chances of the phase terminating before serving the entire queue. If the phase extends too long, decreasing the passage time or the detector length should be considered. This would allow the detector to be unoccupied for less time before terminating.

Using Activity #33: Determining the Length of the Minimum Green Time (Discovery)

Overview

In this activity, students will learn the importance of the minimum green timing parameter and students will also select a minimum green time for their design project. The purpose of this activity is to help students visualize the importance of the minimum green timer. Students will be watching a video and seeing different display outcomes due to different minimum green timer. Students will learn, with the help of the video that one of the primary purposes of the minimum green time is to provide sufficient time for the queue to begin to move before the phase begins to operate under the vehicle extension timer. The minimum green timer needs to be long enough to prevent premature “gap out” due to sluggish queued vehicles just upstream of the detection zone. The vehicle extension time then takes over and maintains the green as long as the headways between vehicles are not longer than the maximum allowable headway.

Options for Use

- Activity #33 can be conducted as part of a sequence of four activities. In each of these four activities, students learn more about the relationship between the minimum green time, the vehicle extension time, and the length of the detection zone.
- The sequence of four activities can be conducted either in class or as homework.

Preparing for the Activity

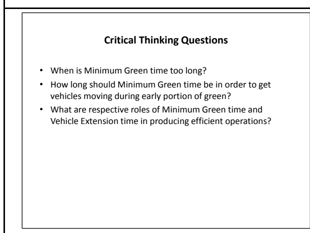
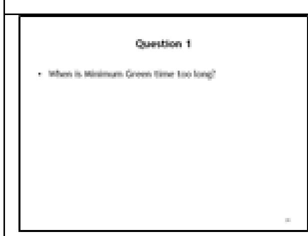
- Watch the video before class.

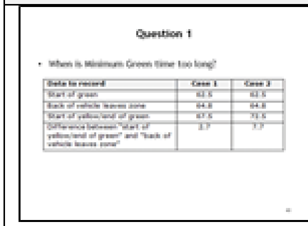
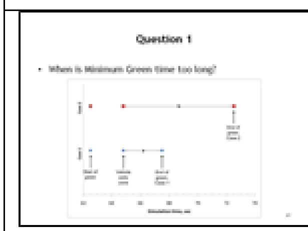
Doing the Activity (Script)

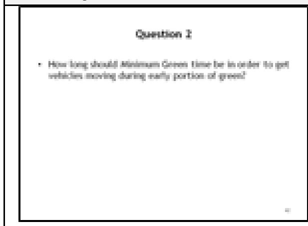
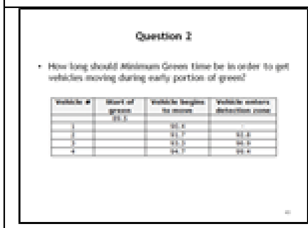
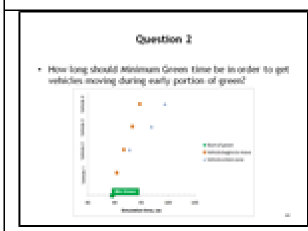
[Slides: slides33.pptx]

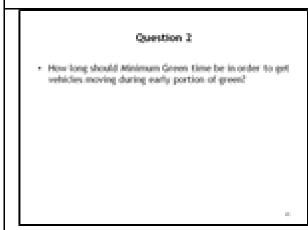
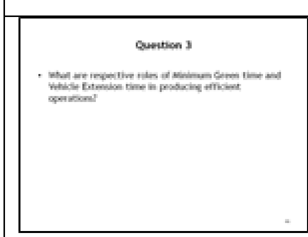
The following script can be used in conjunction with the PowerPoint slides for this activity.

Slide/Action	Script
	**Key Message:** Introduction to Activity #33, Determining the Length of the Minimum Green time. **Background Information:** The learning outcome for this lesson: • Be able to relate the length of the Minimum Green time to the efficient operation of a phase **Interactivity:** **Tell:** Review the activity. It lists the learning outcome for this experiment, an overview of the experiment, the questions that you will answer once you’ve finished the experiment, and the list of steps that you will complete during the experiment. Take about two minutes to read this page.

Slide/Action	Script
	[Once they have completed reading the page] **Tell:** Do you have any questions on this material? **Tell:** Emphasize the learning outcome for this lesson. Be able to relate the length of the Minimum Green time to the efficient operation of a phase. **Background Information:** The Vehicle Extension time is set to 2.2 seconds for phase 4. The Minimum Green time is set to 5 seconds for phase 4 for the first case and 10 seconds for phase 4 for the second case. **Notes:** It is important that the students remember that the “questions to consider” should be kept in mind during the experiment and will serve as the basis for the discussion that will take place when their experiment is concluded.
	**Key Message:** This slide lists the questions for the students to consider, which will be the focus when the students have completed the experiment. **Interactivity:** **Tell:** Review these questions with you partner (if you are working with a partner). Be ready to discuss your answers with the class. **Notes:** Take about 5 minutes for this activity.
	**Key Message:** Consider question 1 and encourage the students to think about it and possible answers. **Background Information:** The Minimum green time settings for case 1 is 5 seconds and for case 2 it is 10 seconds. **Interactivity:** **Ask:** When is the minimum green time too long? **Notes:** Give them a minute or so to collect their thoughts on this question. Then ask for answers.

Slide/Action	Script
	**Key Message:** This slide shows data that are relevant to consider in answering this question. **Interactivity:** **Answer:** The Minimum Green time is too long when the green indication is still on while there are no vehicles standing in queue. Table 5 shows the results of the data collection from the first green indication for cases 1 and 2. The green indication begins at t = 62.5 seconds and the back of the vehicle in queue leaves the detection zone at t = 64.8 seconds. But the green indication ends at different times, depending on the length of the Minimum Green time setting. For case 1, the green indication ends at 5 seconds after the beginning of green, while the green indication ends at 10 seconds after the beginning of green for case 2. **Notes:** Encourage various points of view to be discussed here based on the data that were collected from this experiment (and displayed above).
	**Key Message:** This slide shows graphical relationships of several key points that relate to question 1 on Minimum Green time. **Interactivity:** **Tell:** The chart shows a graphical representation of the data presented in previous table. For case 1, with a Minimum Green time of 5 seconds, the end of green comes 2.7 seconds after the vehicle leaves the detection zone and enters the intersection (line "a" in the chart). For case 2, with a higher Minimum Green time of 10 seconds, the end of green comes 7.7 seconds after the vehicle enters the intersection (line "b" in the chart). In case 2, there is a significant amount of unused green time (7.7 seconds) that is wasted and could be used more efficiently in serving other phases. Clearly, for short queues (in this example, a queue of one vehicle) a shorter Minimum Green time provides a more efficient termination of the phase. As you will see in the next activity, it is the function of the Vehicle Extension time to make sure that the phase continues to time as long as a queue is present and to terminate the phase when the queue has been served. Asking the Minimum Green timer to take care of this function (with longer settings) only results in inefficient use of green time.

Slide/Action	Script
	**Key Message:** Consider question 2 and encourage the students to think about possible answers based on what they observed during the experiment. **Interactivity:** **Ask:** How long should the Minimum Green time be in order to get vehicles moving during the early portion of green?
	**Key Message:** Encourage the students to think about the data that they have collected and how this helps them to consider the role of the Minimum Green time. **Interactivity:** **Answer:** The table shown in the slide shows data collected for the second green indication presented in the simulation for the SB approach, for case 1 (Minimum Green time is set at 5 seconds). Minimum green time starts at t= 89.5 sec and ends at t = 94.5 sec, vehicles begin to move and enter the detection zone during the minimum green time.
	**Key Message:** A graphical representation is useful to help to visualize key relationships. Here students can "see" some of the events that occur at the beginning of green, when the queue begins to start up and travel through the intersection. **Background Information:** The Minimum Green time starts at t = 89.5 sec and ends at t = 94.5 sec. **Interactivity:** **Tell:** This chart shows a graphical representation of the data shown in previous table. Vehicle 1 begins to move 0.9 seconds after the beginning of green. Thus vehicle 1 "gets going" during the Minimum Green duration. Vehicle 2 also begins to move and continues its movement into the detection zone during the Minimum Green period. It is important to remember from Lesson#2 that the longer the detection zone, the less likely the phase will terminate prematurely because of slowly starting vehicles. For example, a 66 foot detection zone would eliminate any start-up concerns regarding the first three vehicles in the queue. All three vehicles would be present in the zone at the beginning of the green indication, so the call would remains active and the phase would continue to time as long as at least one of these vehicles remains in the zone (until, of course, the Maximum Green timer expires). A Minimum Green time of 5 seconds, for the example presented here, provides a reasonable length of time for the queue to begin to move

Slide/Action	Script
	out of the 22 foot detection zone. Other factors may also contribute to the Minimum Green time setting used in practice by a local or state jurisdiction. For example, suppose that one vehicle waiting in queue makes a right turn on red after phase 4 has been selected as "Next." While the phase has called, the calling vehicle has left the zone. A driver upstream of the intersection may observe the following indications: red, either no green or a very short green, yellow, and red. While this is an efficient operation, the upstream driver may report a problem due to the short or non-existent green.
	**Key Message:** There are other sources that provide information on signal timing parameters. **Interactivity:** **Tell:** It is useful at this point to note guidance from the "*Traffic Signal Timing Manual*" [5]: "The Minimum Green interval represents the least amount of time that a green signal indication will be displayed for a movement. Minimum Green is used to allow drivers to react to the change to green at the start of the phase and meet driver expectancy. Its duration may also be based on considerations of queue length. A Minimum Green that is too long may result in wasted time at the intersection; one that is too short may not allow the intersection to time efficiently. Minimum Green time may also be used to allow for pedestrian crossing in the case where pedestrian indications are not used." And: "The intent of the Minimum Green interval is to ensure that each green is displayed for a length that will satisfy driver expectancy." The manual also notes that agencies commonly set Minimum Green time as low as 2 seconds and as high as 15 seconds. Is this practice reasonable based on your observations in Lesson #3?
	**Key Message:** Consider question 3 and encourage students to consider their answers to this question. **Interactivity:** **Ask:** What are the respective roles of Minimum Green time and Vehicle Extension time in producing efficient operations? **Answer:** One of the primary purposes of the Minimum Green time is to provide sufficient time for the queue to begin to move before the phase begins to operate under the Vehicle Extension timer. It needs

Slide/Action	Script
	to be long enough to prevent premature "gap out" due to sluggish queued vehicles just upstream of the detection zone. The Vehicle Extension time then takes over and maintains the green as long as the headways between vehicles are not longer than the maximum allowable headway. We suggest that the Minimum Green and Vehicle Extension time parameters must be determined in a systematic process, clearly understanding the interrelated roles and functions of each timing parameter. These timing parameters are also closely related to the length of the detection zone. When the signal display changes to green, drivers react and begin to move into the intersection. The role of the Minimum Green parameter is to make sure that the queue has sufficient time to begin to move into the intersection. Once the queue is moving, the role of the Vehicle Extension time parameter is to either continue the green as long as headways remain less than the maximum allowable headway (which means that the queue is still clearing) or to terminate the green when a headway exceeds the maximum allowable headway (which usually means that the queue has cleared).

Solution

Critical Thinking Questions and Answers

Students are asked to complete 2 tables and answer questions. Table 1 and Table 2 are listed below with the filled in tables.

Table 1: Task 3 comparing different minimum green times

Data to record	Case 1	Case 2
Start of green	62.5	62.5
Back of vehicle leaves zone	64.8	64.8
Start of yellow/end of green	67.5	72.5
Difference between "start of yellow/end of green" and "back of vehicle leaves zone"	2.7	7.7

Table 2: Task 4 data collection table

Vehicle #	Start of green	Vehicle begins to move	Vehicle enters detection zone
	89.5		
1		90.4	
2		91.7	92.8
3		93.3	96.9
4		94.7	99.4

1. When is the Minimum Green time too long?

- Table 1 shows the results of the data collection from the first green indication for cases 1 and 2. The green indication begins at t = 62.5 seconds and the back of the vehicle in queue leaves the detection zone at t = 64.8 seconds. But the green indication ends at different times, depending the length of the Minimum Green time setting. For case 1, the green indication ends at 5 seconds after the beginning of green, while the green indication ends at 10 seconds after the beginning of green for case 2.

2. How long should the Minimum Green time be in order to get vehicles moving during the early portion of green?

- Table 2 shows data collected for the second green indication presented in the simulation for the SB approach, for case 1 (Minimum Green time is set at 5 seconds). A Minimum Green time of 5 seconds, for the example presented here, provides a reasonable length of time for the queue to begin to move out of the 22 foot detection zone. Other factors may also contribute to the Minimum Green time setting used in practice by a local or state jurisdiction. For example, suppose that one vehicle waiting in queue makes a right turn on red after phase 4 has been selected as "Next." While the phase has called, the calling vehicle has left the zone. A driver upstream of the intersection may observe the following indications: red, either no green or a very short green, yellow, and red. While this is an efficient operation, the upstream driver may report a problem due to the short or non-existent green.

3. What are the respective roles of Minimum Green time and Vehicle Extension time in producing efficient operations?

- One of the primary purposes of the Minimum Green time is to provide sufficient time for the queue to begin to move before the phase begins to operate under the Vehicle Extension timer. It needs to be long enough to prevent premature "gap out" due to sluggish queued vehicles just upstream of the detection zone. The Vehicle Extension time then takes over and maintains the green as long as the headways between vehicles are not longer than the maximum allowable headway.

Using Activity #34: Understanding the Variation of Vehicle Headways in a Departing Queue (Discovery)

Overview

The purpose of this activity is to observe variations of headway within a queue. This will help students select a maximum allowable headway for future activities.

There are two questions which students often ask while completing activity 34. The first question is how to calculate headway. Headway can be calculated as the difference between when the leading vehicle crosses the stop bar and the time when the following vehicle crosses the stop bar. The second question is why there is no headway associated with vehicle one. Because vehicle one is the first vehicle in queue, it is not following another vehicle, meaning that only headways after vehicle one can be calculated. This is important for students to understand when completing activity 36, or their frequency distribution charts will have inaccurate headway data, artificially raising the average queued headway.

Options for Use

- Activity #34 can be conducted as part of a sequence of four activities. In each of these four activities, students learn more about the relationship between the minimum green time, the vehicle extension time, and the length of the detection zone.]
- The sequence of four activities can be conducted either in class or as homework.

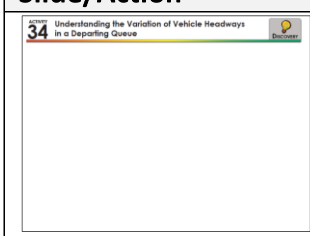
Preparing for the Activity

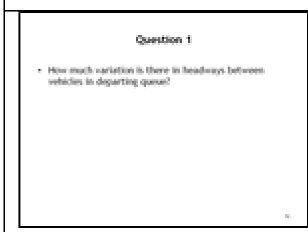
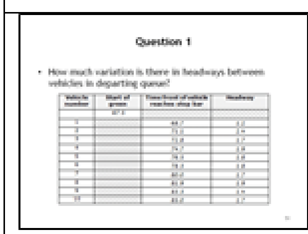
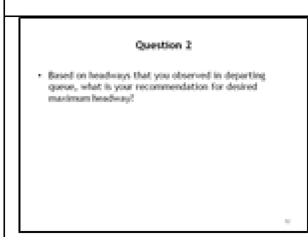
- Watch the video before class.

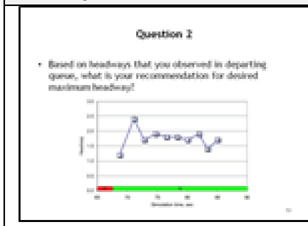
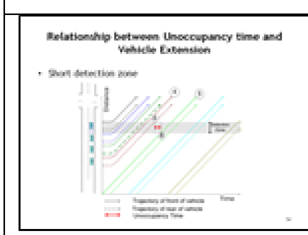
Doing the Activity (Script)

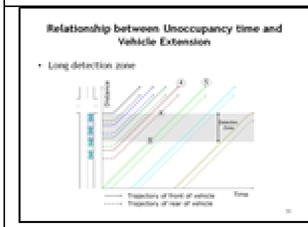
[Slides: slides34.pptx]

The following script can be used in conjunction with the PowerPoint slides for this activity.

Slide/Action	Script
	**Key Message:** Introduction to Activity #34 – Observing Vehicle Headways In The Departing Queue. **Background Information:** The learning outcomes for this lesson: • Understand the variation of vehicle headways in a departing queue. • Be able to establish a desired maximum allowable headway. **Interactivity:** **Tell:** The activity lists the learning outcome for this experiment, an overview of the experiment, the questions that you will answer once you've finished the experiment, and the list of steps that you will complete during the experiment.

Slide/Action	Script
	Take about two minutes to read this page. [Once they have completed reading the page] **Tell:** Do you have any questions on this material? **Tell:** Emphasize the learning outcome for this lesson. Understand the variation of vehicle headways in a departing queue Be able to establish a desired maximum allowable headway **Notes:** It is important that the students remember that the "questions to consider" should be kept in mind during the experiment and will serve as the basis for the discussion that will take place when their experiment is concluded.
	**Key Message:** Consider question 1 and encourage the students to think about this question relates to the data that they have collected. **Interactivity:** **Ask**: How much variation is there in the headways between vehicles in the departing queue? [Student should consider the data that they collected during the experiment.]
	**Key Message:** It is important to understand the traffic flow characteristics of a departing queue when you are setting signal timing parameters. **Interactivity:** **Answer:** The headways for the first three vehicles vary from a low of 1.2 seconds to a high of 2.4 seconds, reflecting the start-up time at the beginning of green as the queue begins to move. After the queue is moving at normal speeds (vehicles 4 through 10), the headways vary from 1.4 to 1.9 seconds, with a mean headway of 1.7 seconds. This is the saturation headway.
	**Key Message:** Encourage the students to consider how the headway data relate to the maximum desired headway. **Interactivity:** **Ask:** Based on the headways that you observed in the departing queue, what is your recommendation for the desired maximum allowable headway?

Slide/Action	Script
	**Key Message:** This chart shows graphically the variation in headway over time. **Interactivity:** **Answer:** Check the headways for vehicle 4 and all following vehicles, since the Minimum Green time should account for the start-up of the queue, covering the first three vehicles. The chart shows the time-series plot of the headways for each vehicle in queue after the start of green. For vehicles 4 through 10, the mean headway is 1.7 seconds, and the maximum headway is 1.9 seconds. If our objective is to make sure that this standing queue is served before the green indication terminates, the Vehicle Extension time must be set to accommodate headways of at least 1.9 seconds. Just to be conservative, you will set the desired maximum headway at 2.0 seconds. It is extremely important to note that Vehicle Extension is set based on unoccupancy time, which is a function of vehicle headway, detector length, and vehicle length. This is discussed further below. And, we'll learn how to set the Vehicle Extension time based on this headway in the next Lesson. It should also be pointed out that these measurements are for a stream of passenger cars only, and you may need to select a higher value when heavy vehicles or slowly reacting passenger cars are in the traffic stream.
	**Key Message:** This chart shows the relationship between unoccupancy time and Vehicle Extension using a short detection zone. **Interactivity:** **Tell:** In the field, traffic control systems using presence detection don't typically measure flow rates or headways but rather the unoccupancy time. The unoccupancy time is the time that a detection zone is unoccupied (does not register a call), measured from the departure of the rear end of one vehicle to the arrival of the front end of the following vehicle in the detection zone. When the unoccupancy time exceeds the Vehicle Extension time, the phase will terminate, assuming the Minimum Green timer has also expired and no other special features are active. The unoccupancy time depends directly on the length of the detection zone, as well as the vehicle speed (which may vary over time) and vehicle length, as shown in the slide. The horizontal distance between points A and B (red arrow) represents the unoccupancy time, the time

Slide/Action	Script
	between when vehicle 4 leaves the detection zone and vehicle 5 arrives in the detection zone. After point A, the Vehicle Extension timer will begin to time down. The Vehicle Extension timer will be reset at point B, as long as the time interval between A and B is less than the Vehicle Extension time.
	**Key Message:** This slide shows the relationship between unoccupancy time and Vehicle Extension using long detection zone. **Interactivity:** Tell: The slide shows that, with a longer detection zone, the event represented by point B occurs before that represented by point A (vehicle 5 arrives in the detection zone before vehicle 4 leaves the zone), so the unoccupancy time is zero. In this case, the Vehicle Extension timer will not begin to time and the phase will continue (as long as the Maximum Green timer has not expired). You will consider the relationship between the headway, the unoccupancy time, and the Vehicle Extension time in Lesson #5.

Solution

Critical Thinking Questions and Answers

1. How much variation is there in the headways between vehicles in the departing queue?
- The first headway is significantly larger than the subsequent headways, however, after the second vehicle passes the stop bar, the headways are fairly consistent, with the mode headway being 1.9 seconds and the minimum headway being 1.6 seconds.

2. Based on the headways that you observed in the departing queue, what is your recommendation for the desired maximum allowable headway?
- The recommended maximum allowable headway would be 2 seconds. This maximum allowable headway would be sufficient for all but the second vehicle, which will not matter as much because the minimum green timer will still be active when it reaches the stop bar.

Table 3. Data Collection Table

Vehicle number	Start of green	Time front of vehicle reaches stop bar	Headway
	67.4		
1		68.4	-
2		70.8	2.4
3		72.7	1.9
4		74.6	1.9
5		76.5	1.9
6		78.2	1.7
7		79.9	1.7
8		81.9	2.0
9		83.3	1.6
10		84.9	1.6

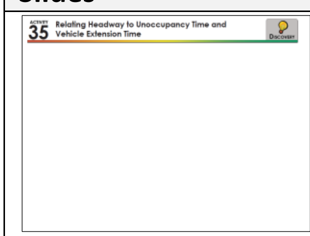
Using Activity #35: Relating Headway to Unoccupancy Time and Vehicle Extension Time (Discovery)

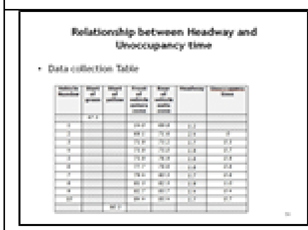
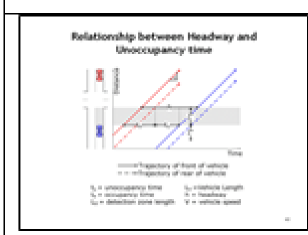
Overview
In this activity, students will learn about the relationship between unoccupancy time and vehicle extension time. The goal of activity #35 is to teach students the relationship between maximum allowable headway and unoccupancy time and to determine the vehicle extension time using detection zone length and maximum allowable headway. Students are first asked to watch a video and collect data to calculate the unoccupancy time.

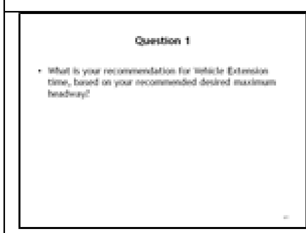
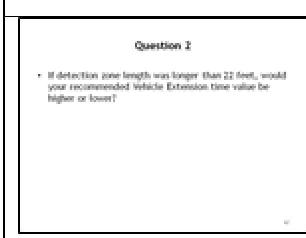
Options for Use
- Activity #35 can be conducted as part of a sequence of four activities. In each of these four activities, students learn more about the relationship between the minimum green time, the vehicle extension time, and the length of the detection zone.
- The sequence of four activities can be conducted either in class or as homework.

Preparing for the Activity
- Watch the video before class.

Doing the Activity (Script)
[Slides: slides35.pptx]
The following script can be used in conjunction with the PowerPoint slides for this activity.

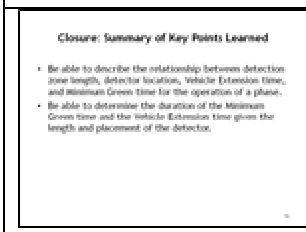
Slides	Text
	**Key Message:** Introduction to Activity #35, Relating Headway to Unoccupancy Time and Vehicle Extension Time. **Background Information:** The learning outcomes for this activity: • Be able to relate the maximum allowable headway to unoccupancy time. • Be able to determine the Vehicle Extension time based on the length of the detection zone and the desired maximum allowable headway. **Interactivity:** **Tell:** Review the learning outcomes for this experiment, an overview of the experiment, the questions that you will answer once you've finished the experiment, and the list of steps that you will complete during the experiment. Take about two minutes to read this page. [Once they have completed reading the page]

Slides	Text
	Tell: Do you have any questions on this material? **Tell:** Emphasize the learning outcome for this lesson. Be able to relate the maximum allowable headway to unoccupancy time Be able to determine the Vehicle Extension time based on the length of the detection zone and the desired maximum allowable headway **Notes:** It is important that the students remember that the “questions to consider” should be kept in mind during the experiment and will serve as the basis for the discussion that will take place when their experiment is concluded.
	**Key Message:** This table shows data that help the student understand the relationship between headway and unoccupancy time **Interactivity:** **Tell:** This table shows the results from observing the simulation. The green time begins at t = 67.5. The headway data collected earlier are also included in this table. The important point is the relationship between the headway and the unoccupancy time. For vehicles served after the Minimum Green time expires (vehicles 4 through 10), the unoccupancy time is about one second less than the headway. **Ask:** Is this a consistent and stable value, and if so why?
	**Key Message:** This slide shows a graphical representation of the relationship between headway and unoccupancy time **Interactivity:** **Tell:** This chart shows the formal relationship between the headway and the unoccupancy time. Suppose vehicles 1 and 2 are separated by the desired maximum headway, h. This headway consists of two parts, the time that the detection zone is occupied (t_o) and the time that the detection zone is unoccupied, or the unoccupancy time (t_u). $$h = t_o + t_u$$ The occupancy time (t_o) is the sum of the time it takes for a vehicle to travel both its own length (L_v) and the length of the detection zone (L_D), traveling at speed v.

Slides	Text
	$t_o = \frac{L_v + L_D}{v}$ In this case, for the data given, the occupancy time (t_o) is 1 second. The unoccupancy time is then related to the desired maximum headway according to the following equation: $t_u = h - t_o = h - \frac{L_v + L_D}{v}$ And, why is this relationship important? This is a critical relationship that will help us to set the Vehicle Extension time, once we've agreed to a desired maximum headway. The Vehicle Extension time should be set to the unoccupancy time that is equivalent to the desired maximum headway. Based on this relationship, for a desired maximum headway of 2.0 seconds (for the headway characteristics measured in Lesson#4), the Vehicle Extension time should be set to 1 second: $t_u = h - t_o = 2.0 - 1.0 = 1.0$
	**Key Message:** Consider question 1 and encourage the students to think about possible answers based on their observations from the experiment. **Interactivity:** **Ask:** What is your recommendation for the Vehicle Extension time, based on your recommended desired maximum headway? **Answer:** Assuming that the desired maximum headway is 2.0 seconds (based on Activity #xx), the Vehicle Extension time should be 1.0 seconds. This is based on the relationship between unoccupancy time and headway that was described earlier: $t_u = h - t_o = 2.0 - 1.0 = 1.0$
	**Key Message:** Encourage the students to consider question 2 and possible answers based on their observations during the experiment. **Interactivity:** **Ask:** If the detection zone length was longer than 22 feet, would your recommended Vehicle Extension time value be higher or lower? **Answer:** If the detection zone is increased above 22 feet, the Vehicle Extension time should be lowered. Why? A longer zone will increase the occupancy time, and as shown by the equation below, the

<table>
<tr><th>Slides</th><th>Text</th></tr>
<tr><td></td><td>unoccupancy time (and thus the Vehicle Extension time) is less.

$$t_u = h - t_o = h - \frac{L_v + L_D}{v}$$

The primary advantages of a longer detection zone are (1) a smaller chance of a premature phase termination due to the sometimes sluggish start-up of the first several vehicles over the detection zone and (2) a shorter loss time due to the Vehicle Extension timer extending the phase after the last queued vehicle leaves the detection area.</td></tr>
<tr><td>
</td><td>Key Message:
This slide encourages the students to consider the key points covered during the four activities in this set.
Interactivity:
Ask: What did you learn in these four activities?
Tell: In this class, you looked at the factors that should be considered when the Minimum Green time and the Vehicle Extension time parameters are set, for a given length of the detection zone. It should be pointed out that we’ve only considered stop bar detection, and other detection zone configurations will result in different results.

You saw in Activity #20how a phase times, and two common ways in which a phase is terminated: (1) the Minimum Green and Vehicle Extension timers both expire, resulting in a “gap out,” and (2) the Maximum Green timer expires, resulting in a “max out.”

You saw in Activity #32 that the detection zone itself can provide some extension of the green as vehicles arrive at the intersection and enter the zone. A longer zone provides more of this extension capability.

In Activity #33, you learned how the Minimum Green time must be set long enough so that the queue begins to move but short enough so that the phase doesn’t extend inefficiently when very short queues are present.

In Activities #34 and #35, you learned about the desired maximum headway, how it relates to the unoccupancy time, and how both factors help to set the Vehicle Extension time.

It should also be noted that some agencies use 40 foot, 60 foot, and occasionally longer detection zones to keep Minimum Green and Vehicle Extension times to their lowest practical values.</td></tr>
</table>

Solutions

Table 4: Task 2 solution table

Vehicle Number	Start of green	Start of yellow	Front of vehicle enters	Rear of vehicle exits zone	Headway	Unoccupancy time
	67.5					
1			**14.0**	**69.8**	1.2	
2			**69.4**	**71.6**	2.4	**0**
3			**71.9**	**73.2**	1.7	**0.3**
4			**73.9**	**75.0**	1.9	**0.7**
5			**75.9**	**76.9**	1.8	**0.9**
6			**77.7**	**78.6**	1.8	**0.8**
7			**79.4**	**80.3**	1.7	**0.8**
8			**81.3**	**82.3**	1.9	**1.0**
9			**82.7**	**83.7**	1.4	**0.4**
10			**84.4**	**85.4**	1.7	**0.7**
		90.3				

Critical Thinking Questions and Answers

1. What is your recommendation for the Vehicle Extension time, based on your recommended desired maximum headway?

- Assuming that the desired maximum headway is 2.0 seconds, the Vehicle Extension time should be 1.0 seconds. This is based on the relationship between unoccupancy time and headway:
  $t_u = h - t_o = 2.0 - 1.0 = 1.0\ sec$

2. If the detection zone length was longer than 22 feet, would your recommended Vehicle Extension time value be higher or lower?

- If the detector was greater than 22 feet, the Vehicle Extension time value will be smaller.

Using Activity #36: Determining the Maximum Allowable Headway (Design)

Overview

In this activity, students will determine the maximum allowable headway for their design project. The purpose of this activity is to provide students with the basis for determination of their maximum allowable headway. The maximum allowable headway is the largest headway that you will tolerate in a departing queue before the phase will/should terminate. The choice of this headway involves balancing two conflicting and competing issues: if the headway that you select is too small, then you run the risk of terminating the phase too soon and not serving all of the vehicles in the queue that formed during red. However, if the headway that you select is too large, then you run the risk of allowing the phase to extend too long, serving not just the initial queue but also vehicles that arrive after the initial queue has cleared. The problem comes in recognizing that some of the headways that you observe after the queue has cleared might be in the same range as those that you observed during the queue clearance. The choice that students make in the value of the maximum allowable headway should reflect some risk of both conditions: (1) cycle failure, or not all of the initial queue being served and (2) inefficient extension of the green, resulting in longer delays on the other approaches. You will try to balance these two risks.

Options for Use

- Activities #36 and #37 are usually done during class time in a computer lab with VISSIM and Excel.

Preparing for the Activity

- Review the tasks that the students will do.
- Review the data set and solutions to get an understanding of what the students will be doing and observing.
- Review section on "Skills and Conceptual Issues" to learn about common student misconceptions and problems with this activity.

The concept of a phase termination analysis is introduced to allow students to see the effects that headway has in either serving too few or too many vehicles. To complete a phase termination analysis, three types of termination are must be understood.

- The first termination type (Termination Type I) occurs when the phase terminates before all of the queued vehicles have been served. Frequent Type I Terminations indicate that the maximum allowable headway is too small and should be increased to better serve the demand.
- The second termination type (Termination Type II) occurs when the phase terminates after serving one or more non-queued vehicles. Frequent Type II Terminations indicate that either the maximum allowable headway is too large, or vehicles in the opposite direction are extending the phase past the ideal termination point for the direction of study.

- The final termination type (Termination Type III) occurs when the phase terminates after serving all queued vehicles but before serving any non-queued vehicles. Type III Terminations are ideal, but are also the least likely to occur.
- Finally, it is important to note that while not serving a few queued vehicles or serving a few non-queued vehicles causes a Type I or Type II Termination, the impact this will have on performance is not nearly as much as if a large number of vehicles are unnecessarily served. This is something students should consider while selecting their maximum allowable headway.

How does phase termination work?
The termination analysis template is broken down into three major columns; Ideal Signal Display, Change Occurs and Termination Outcomes. The Ideal Signal Display column is responsible for the majority of the work in the termination analysis by locating where a signal will gap-out given a maximum allowable headway (MAH). The gap-out occurs when the ideal signal display column changes from
“Green” to “Red” and is tracked in the Change Occurs column with the word “Change”. The final set of columns determines what type of termination has occurred by comparing where the “Change” occurred with respect to the ideal signal display, “Green” or “Red”.

Ideal Signal Display
Below is a breakdown of the Ideal Signal Display formula down into the basic logical statements used. The logic is broken down into three sections which can be seen in Figure 3 and will be called the blue, orange and purple sections. The blue section checks if the queued or nonqueued headway is greater than the selected maximum allowable headway (MAH). If the headway is headway is greater, the output will be “Red” and all of the subsequent outputs will be “Red” as well until a new cycle starts. The orange section of the logic starts a new cycle with a “Green” display and the last output in a cycle to be “Red”. This means that no gap-out can occur for the first headway when tends to be larger than other queued headways and for a real signal the vehicle would be sitting on the detector during this time. Previously, the first headway (between the first and second vehicle in queue) was ignored but with 2 lanes, the headway between the first and second vehicle switches to be the second headway in the list. The purple section of the logic attempts to handle this switch.

```
=IF(AND(A19="",B19=""),"Red",(IF(AND(A17="",B17=""),"Green",IF(AND(A16="",B16="",A19>A18),
"Green",IF(AND(A18="",B18=""),"",IF(C17="Red","Red",IF(MAX(A18,B18)>=$A$7,"Red","Green"))))))
```

Figure 3: Ideal Signal Display Code

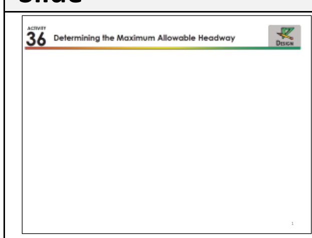
It should be noted that Activities 36 and 37 are the most demanding activities in the book, and as such will require more effort from the students and more preparation from the instructor. Additionally, because students will be making several temporary changes to their network, they should be encouraged to make a backup copy of their VISSIM files so that they can easily revert back to previous iterations of their simulation.

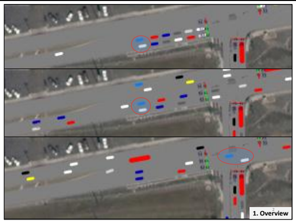
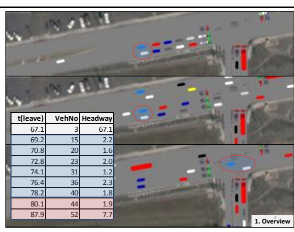
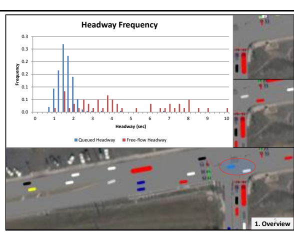
Skills and Conceptual Issues This activity is very challenging for students in several ways. While a revision to the activity text might be in order at some point, the following discussion might help the instructor prepare for the challenges that are likely to occur. These issues can be organized into four categories: 1. Excel skills 2. VISSIM skills 3. Statistical skills 4. Transportation concepts, particularly dealing with the definition and use of the MAH and the theory and application of the PTA. Excel skills: • Parse text data file into columns • Manipulate rows and columns of data • Sort data by criterion • Use logical (If) statements • Create frequency data from data • Create frequency plots	VISSIM skills: • Increase demand on link • Set signal timing parameters • Set data collection point • Select/configure “data collection evaluation file Statistical skills: • Create and interpret frequency and cumulative frequency plots Traffic concepts/knowledge: • Define MAH • Define types of phase termination (and desirability of each) • Distinguish between queued and non-queued vehicles • Select MAH, trading off competing Types 1 and 2, using phase termination analysis results • Describe concept of PTA and components of the analysis process

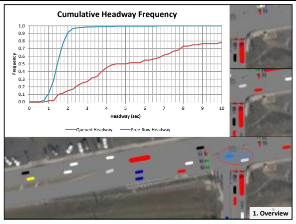
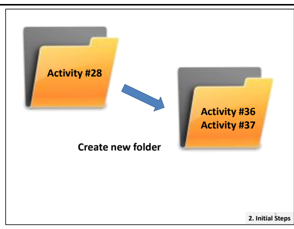
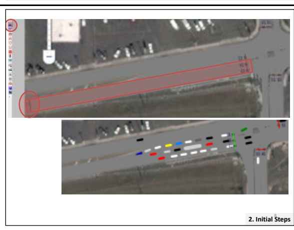
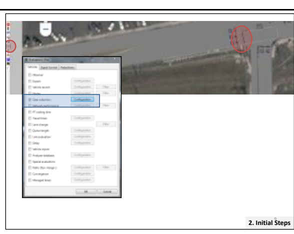
Doing the Activity (Script)

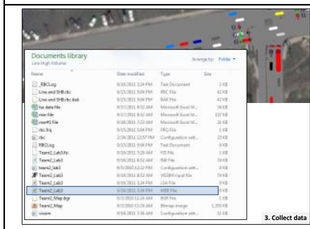
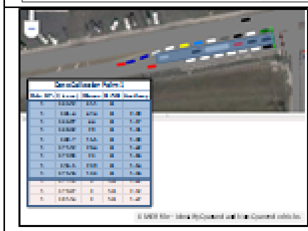
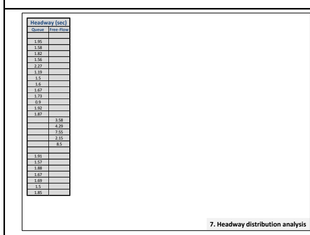
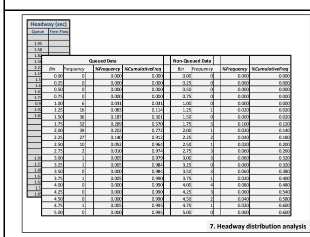
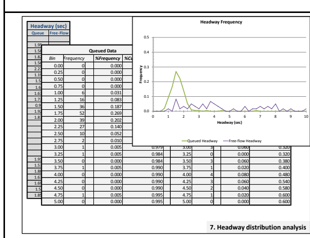
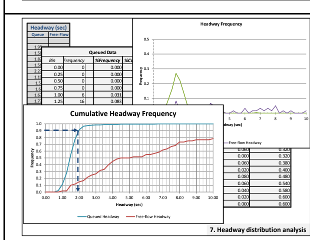
[Slides: slides36.pptx]

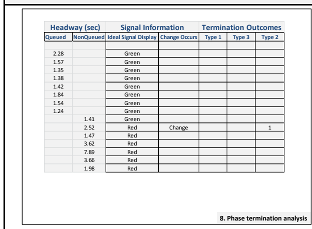
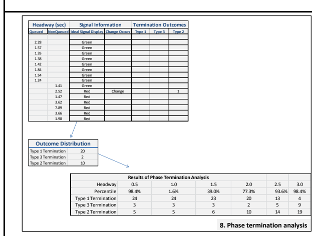
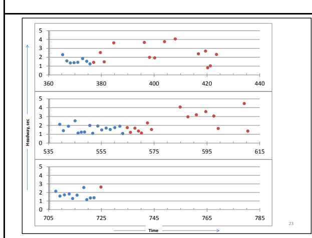
- This module consists of two activities in which students will observe and collect data using VISSIM to determine values for maximum allowable headway and passage time.
- The instructor will guide a discussion based on the results of the students’ experimental analysis and design work.

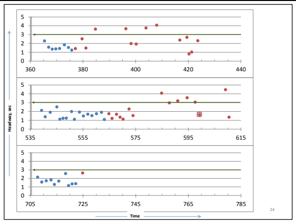
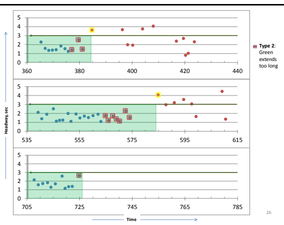
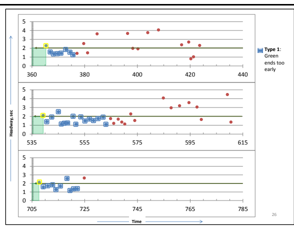
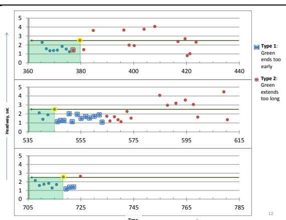
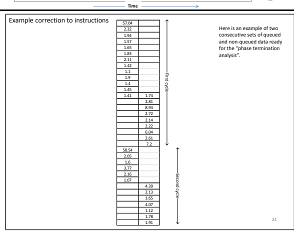
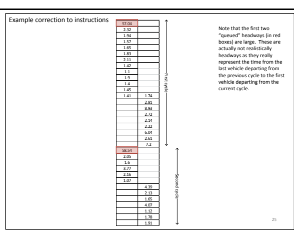
Slide	Text
	To be very succinct: the major outcome of this activity is for you to determine the MAH that you will tolerate in a departing queue before you want to terminate a phase. This choice involves balancing two conflicting or competing issues: if the headway that you select is too small then you will run the risk of terminating the phase too soon and not serving all of the vehicles in the queue that formed during red. However, if the headway that you select is too high, then you run the risk of allowing the phase to extend too long, serving not just the initial queue but also vehicles that arrive after the initial queue has cleared. In summary: • Type 1: cycle failure (or “phase failure”, initial queue not served. • Type 2: inefficient extension of green, longer delays result.

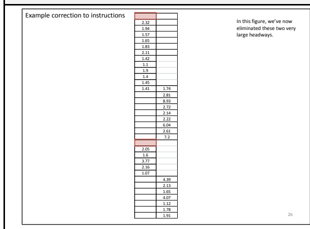
Slide	Text
	To be able to determine the MAH, you will have to complete several tasks, and make several choices. Let's look at some pictures to illustrate some of these issues and choices: Here are the three pictures of a departing queue. • First we see the queue of six vehicles in each lane at the start of green. • Next: by the time the queue begins to move, a seventh vehicle has joined the queue. This is how we will define the queue. All vehicles that were in the queue at the beginning of green, and any vehicles that join this queue after green begins, but before the whole queue begins to move. • Finally: The queue is now moving, spreading out. The original "back of queue" vehicles (in standing queue) are in the intersection while the "newbie" (joining queue after beginning of green) is just about to enter the intersection.
	Now another issue to determine is what is the headway distribution, for both queued vehicles and for vehicles that enter after the queue has cleared (which we will call "non-queued" vehicles or free-flow vehicles). [start video] This video shows a queue of six vehicles at the start of green. As the queue clears, the headways between each vehicle pair is shown. Headways range from 1.2 sec to 2.3 sec. Even the vehicle that arrives the white vehicle has a headway that appears to be in the range of "queue" headway (1.9 sec), but this is definitely a non-queued vehicle. The next vehicle arrives 7.7 seconds later, definitely a "non-queued" vehicle.
	Here is a tabular representation of what we just saw. Queued vehicles are in a narrow range, while the "non-queued" vehicles are more highly variable. That 1.9 sec example is part of the problem. It looks like a Q headway, but is not! That is part of the risk in this phase termination and in selecting the MAH to minimize this risk.
	In addition to looking at tables of values as in the previous slide, you will also look at distributions. Here is the frequency distribution showing the queued headway vehicles (which are in the narrow band of 1-2 sec, while the NQ vehicles do have small values (1-2 sec) but are highly diverse with values up to 7-10 sec as well.

Slide	Text
	Another representation that you will use is the cumulative frequency plot. What value is this? Suppose your goal is setting the MAH is that you want to increase a given percentage of headways, say 95%, to minimize the risk of early termination, you can look at a cumulative frequency plot: 90% for blue line = headway of 2 sec 80% = headway of 1.8 sec So: major goal of this activity is to weigh the two competing risks and select your MAH. In order to collect the data that you will need for your headway analysis, you will use VISSIM to collect the headway data. There are several initial steps to complete before you can run the simulation and collect the data.
	File management. You will be creating new VISSIM files and each new file should be associated with a new activity. So, make a copy of your base simulation network files and create a new folder: “A36”.
	Next, you need to make a choice on the phase that you will study and the specific lane on which you will collect data. You also need to increase the volume on this approach so that you will generate queues of 10-15 vehicles at the beginning of green in your lane of interest during the VISSIM simulation. This slide shows: • Vehicle input icon. • Input node (at upstream end of link) • Example queue You will need to experiment with the input level that will generate the required queue length but not so long that you can’t see the end of the queue. You should also increase PT = 5 so that you will get sufficient number of NQ vehicles. (MaxG=100?)
	To collect the headway data you need to establish a “data collection” point just immediately downstream of the signal heads: • Data collector icon. • Data collector location. • Evaluation file: “data collection”. Summary/Recap 1. Create new folder for A#36. 2. Select lane for study. 3. Increase volume to generate desired queues.

Slide	Text
	4. Add data collection point. 5. Select evaluation files.
	Collect Data. You are now ready to collect the data and generate the evaluation files. • Run VISSIM for 3600 sec. • Find MER file.
	Identify Q and NQ vehicles in MER file. 1. Open and parse MER file in Excel. 2. Keep only t(leave) and Veh# 3. Eliminate t(leave) = -1 4. Compute headways between vehicles 5. Determine Q or NQ for each vehicle based on whether the tQueue>0 or not. 6. Save this in Excel file.
	Headway Distribution Analysis. This next set of steps will produce statistical analysis of headway data. Start with chronological list of Q and NQ (free flow) headways for t=300 to t=3600.
	Create bin range in 0.25 sec intervals. Use Excel data analysis (histogram) to produce frequency data.
	Here are the frequency distributions for both the Q and NQ vehicles. Note that even after the queue clears (NQ), there are still headways that mimic the departing queue!
	Here are the cumulative frequency distributions. How to interpret: the 90th percentile for the Q vehicles results in a headway of 2.0 sec.

Slide	Text
	The final step in the process for A#36 is to select the MAH. The tool that you will use is called the Phase Termination Analysis. The essence of the PTA is this: you generate a set of headways in the simulation model, using a higher-than-practical passage time (vehicle extension time): 5 seconds. You also set a higher than normal maximum green time: 100 seconds. And, you increase the volume on the approach that you will be studying to a high enough level that will generate beginning-of-green queues of between 10 and 15 vehicles per lane. This is what the PTA template looks like in your Excel spreadsheet for A#36, with the Q and NQ (free-flow) headways pasted into the first two columns. Based on the MAH that you set, the spreadsheet determines when this MAH first occurs in the stream of headway data. The spreadsheet enters the signal display (either G or R) and identifies when the change from G to R occurs. It also identifies whether the "Outcome" is good, or a Type 1 or Type 2 problem. The example shown in this slide lists a set of headways for vehicles in the departing queue (all of the headways are in the Q column). Here the MAH has been set to 2.0 seconds, so the phase would terminate when the vehicle with a headway of 2.52 seconds is reached. The change is a type 2 problem because the phase continues to time (Green) after the queue has been served. In this case it is not a serious problem since only one additional vehicle is served, but this does illustrate the process underlying the PTA.
	This slide shows the results from investigating a range of values for the MAH from 0.5 seconds to 3.0 seconds for the example data set shown here. The "Outcome Distribution" shows the number of Type 1 terminations ("early, queue not served"), Type 2 terminations ("late, inefficient extension of green"), and Type 3 terminations ("just right, Goldilocks!").
	Let's look at the PTA one more time, this time with a graphical perspective. Here is a set of three charts, each showing the headways measured for one green interval for the same intersection approach. The x-axis show the simulation time, for each of these three green intervals. The y-axis shows the headway between each vehicle pair after the start of green. The headways shown in blue were measured for the departing queue; the headways shown in red/brown were measured for vehicles that arrived after the initial queue had cleared.

Slide	Text
	Our goal in the PTA is to assess the effect of imposing various values of the MAH on the given stream of headways to see whether the resulting signal timing serves the vehicles in the queue, or extends beyond the time that the queue clears. In this first example, we set the MAH to 3.0 seconds (see the green horizontal line in each of the three charts).
	This slide shows the effect of MAH = 3 seconds. When a headway in the traffic stream exceeds the MAH, the phase will terminate, shown here by the yellow box surrounding the affected vehicle headway. Then a green box is shown that indicates the duration of the green interval with this assumed MAH, and the vehicles that are served (in the green box) or not (outside of the green box). In each of these three cases, the phase has extended beyond when the queue clears, so each is a Type 2 termination. We can see the vehicles that arrived after the queue had cleared that are nevertheless served (shown with red/brown box).
	Here is another case, this time with a MAH = 2.0 seconds. Here, with the shorter MAH, we see that the phases terminate too early (Type 1) as not all of the vehicles in the departing queue are served.
	Finally, we see an intermediate value (MAH = 2.5 seconds), in which there are both Type 1 and Type 2 terminations.
	Here are some other notes that might be helpful. This slide, and the following two slides, show one of the issues that you have to deal with on the list of headways. The headway calculations that you make will result in a headway (not a true headway), that is the difference in the “leave” time for the first vehicle in queue and the last vehicle that departed during the previous green.
	

Slide	Text
	

Solution

See Excel file for example solutions and additional notes for Activity #36.

Other Notes

This section includes a variety of notes from students on what they learned and issues that they faced in completing this activity.

Two things that you as a team learned about signal timing. 1. Headway should be computed by approach rather than by lane. -->That is true for this assignment since your detectors for each approach work together as a group. So, what does this imply for the computation of the passage time? 2. A passage time of 5 seconds is very long for a detection zone of 66 ft when the traffic volume is high. 3. The detectors work together in one approach, and that the headway is measured for all three east-bound approach lanes. -->See note for "1" above. 4. We learned basically how the headway applies to unoccupancy time and to passage time. 5. We learned how detectors can work together or separately. -->To clarify: detections or calls can occur for an approach or for individual lanes on the approach. While still not in common use, lane by lane detection has been found to be far more efficient. 6. We have learned about detectors on 2 lanes. How they are not separate in a movement, they are on the same approach and need to both be counted. 7. We learned how to find the 85th percentile for headway correctly using a graph. 8. A detector zone's length will affect the length of green time. -->This is one of the most important lessons. A longer zone will generate smaller unoccupancy times, which will in turn generate the need for a smaller passage time. 9. Smaller minimum green time combined with shorter detector zone will give a smaller green interval. 10. Headway should be measured separately for arriving on green and standing queue. Speeds effect these headways. -->Why? We are interested in learning about headways for different period of the green so we separate the measurements to learn about headways in the departing queue and headways for traffic that arrives after the

queue has cleared.

11. We learned how to better calculate the 85th percentile headways using frequency graphs.

12. We learned that headway can come out negative if there are actually two lanes on the same phase with detectors for that phase.
-->Headway values can never be negative. However, unoccupancy time can be computed to be negative (be we always transform a negative value to zero).

13. We learned that when you combine longer detector lengths and longer passage times, the lane is less efficient.
-->Or, that the operation that lane is less efficient.

One question that you as a team still have about these concepts.
1. How does the phase terminate as we got headway=8 sec and we set PT=5 sec but the phase does not terminate after 8 sec?
-->An 8 second headway can occur if the minimum green timer is still timing, but not afterwards.

2. What computation are the larger and smaller computed values from in task 4?
-->Not sure what you mean by "larger and smaller computed values"? Please clarify.

3. Why do we use the mean headway for calculating unoccupancy time with a queue but use the 85th percentile headway for the free flow situation?
-->If you are referring to task 3: both cases are extreme in some sense and your results should provide you with a chance to consider the implications of using certain values as inputs and how they affect the resulting unoccupancy time.

4. Our unoccupancy times seem low. Our first calculated time was negative, and we assumed it to be zero, and the second one is less than half a second. We are wondering if these values are reasonable?
-->Unoccupancy times can be zero if the following vehicle arrives in the zone before the leading vehicle leaves the zone. This is not only reasonable but common, especially for longer detection zones or for multiple lane detection.

5. How do we calculate 85th percentile and should we be doing the std dev and range and 85th percentile calculations for groups (averages of the headway of cars in the queue, averages of the headway of cars out of queue).
-->You can compute the 85th percentile value graphically by plotting the cumulative distribution. And you should do this computation for both groups.

6. Not to sure about how to calculate occupancy and unoccupancy time.
-->Note that the headway is the sum of the occupancy time and the unoccupancy time.

7. We still don't understand what the larger/smaller computed values are on task 4.
-->Again, not sure what "larger/smaller" refers to. Please clarify.

8. Are shorter detection lengths better for higher traffic flows?
-->The relative traffic volume is not the issue. The issue is what part of the green interval are you talking about? For the first part of green, when the queue is discharging (and the traffic flow rate is high), the passage time must be set in relation to the length of the detection zone. Longer zones mean shorter detection zones. But the overall approach flow rate should not be an issue with respect to zone length and passage time. For higher flow rates, the real issue is the maximum green time length.

Reflections

- I mentioned to pretty much all of the groups to put their frequency distributions in % on the y-axis.
- Some groups counted the time that a vehicle was at the light during the red interval as the first headway. This gave them values that were very high, like 50 seconds for a headway. It threw off some of their percentiles and made the equations that JJ/Kevin wrote not work properly.
- The scales on the x-axis for some of the groups were excessive, including headway data out to over 100 seconds.

How the spreadsheet works

- The first column has both queued and non-queued headways. Before each "cycle" there should be a bank row.
- The "Ideal Signal Display" column determines when the signal should change due to a gap out using the critical headway above. The ideal signal display will always be green for the first headway due to allow the vehicles to start up. Also, once the critical threshold has been met, the rest of the ideal signal display will continue to display "R".
- The "Change Occurs" column simply says when the signal changes
- The "Outcomes" row compares if the queue has been cleared yet vs. the ideal signal display and selects the appropriate outcome.

Skills self-assessment from students
Based on the survey done after A36, students assessed their skills. It would be good in this activity to identify what these skills are and to give them a chance to find resources to bolster their skills before undertaking the activity. Also, diagramming the activity and identifying what skills they need to have before undertaking the activity would be helpful.

Also, need to complete tutorial for “10 powerful Excel skills that you will need to complete these activities.”

Category	Skill or Knowledge	Confident	Not Confident
Excel Skills	Parse Text Data File into Columns	18	3
	Manipulate row and columns of data	21	0
	Sort data by criterion	20	1
	Use Logical IF statements	14	7
	Create Frequency Data from Data	17	4
	Create Frequency Plots	18	3
VISSIM Skills	Increase Demand on Link	15	6
	Set Signal Timing Parameters	16	5
	Set Data Collection Point	12	9
	Select/Configure "data collection evaluation file"	12	9
Statistical Skills	Create and Interpret Frequency and Cumulative Frequency Plots	20	1
Traffic Knowledge	Define MAH	19	2
	Define types of phase termination	16	5
	Distinguish between queued and non-queued vehicles	19	2
	Select MAH, trading off competing Types 1 and 2, using the phase termination analysis	16	5
	Describe concept of PTA and components of the analysis process	14	7

Notes for A#36/A37

1. Consider for next edition of book: Reorder the bullets in Task 1 so that students check that their passage time is set to five seconds before they increase their volumes to get their desired queue lengths. That said, a five second passage time is the base case value, so the check may not be necessary at all.

2. In bullet five of Task 1, students are instructed to put a data collection point in "both" lanes of their selected approach. What should groups with only one through lane on their major approach do? I would recommend changing this in future version to something along the lines of "all through lanes" instead of both. However, this seems to raise a much more serious question. What will teams with only one through lane (network03) do for Activity 37?

3. In Task 2 of Activity 36, it should be pointed out that when the data are parsed, the "Data C.P." column heading will be split into two columns, so the headings need to be shifted to the left one column to align everything correctly. If this is not done, students will be likely to use the wrong data for their analysis.

4. To eliminate the abnormally large headways caused by signal changes, students should create an "if statement" that inserts a blank line rather than calculating headway. This was done in the attached Excel file, but basically the idea is that when the Q/NQ column changes from NQ to Q, the headway column should have a blank space rather than calculating headway.

5. In Activity 36, if Task 4 is done before Task 3, Task 3 will be easier to complete.

6. Also, in Task 4, students are shown a figure (figure 126) which still has a column for "VehicleNo". Students were instructed to delete it in figure 120, but it is also in figure 121 and 122. Vehicle number is never actually used, but it is useful for making visual checks of the data so that we could identify vehicles that seemed odd based on the data results, for example, if a non-queued vehicle had a very low headway that seemed wrong, we could identify it in VISSIM much easier if we still had the vehicle number. In summary: When Task 4 is started, it was assumed, based on figure 126, that the vehicle number was needed in the data set for the rest of the analysis. While this is wrong, it could be useful for students to know they don't need to reparse their data to include it. Also, having the vehicle number in the data set can be useful for data verification.

7. Should Task 5 of Activity 36 or Task 2 of Activity 37 go on tab 7 of the excel file students are creating? Currently, there is nothing the students are told to put there, and neither of these tasks have a sheet associated with them. In my opinion, it would make more sense to put Task 2 of Activity 37 there because it requires more data analysis which is less related to previous work.

8. Because students need the speed data in Task 2 of Activity 37, they should not delete the velocity column in Task 2 of Activity 36. It is common to go back to the raw data and starting over for several tasks when better instructions at the beginning could have saved a decent bit of time.

Using Activity 37: Determining Passage Time (Design)

Overview

The purpose of this activity is to improve student understanding of the relationship between detection zone length, passage time, and minimum green time through observation of simulations, the collection and analysis of performance data, and through an analysis of the unused green time. Students should be able to selected timing and detector parameters.

Students will first select the detection zone length information collected from the previous activity which includes maximum allowable headway, speed, and vehicle length. Then students will select the minimum green time based off of unused green time. Students will then answer questions.

Options for Use

This activity is generally used in conjunction with Activity #36 and is done in the computer lab.

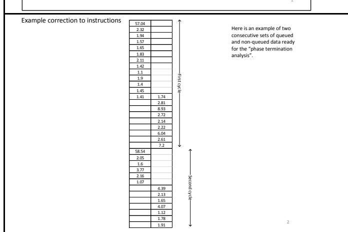
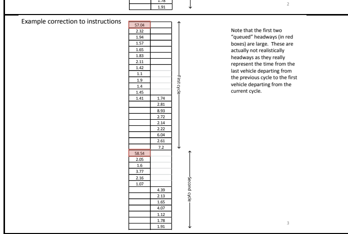
Preparing for the Activity

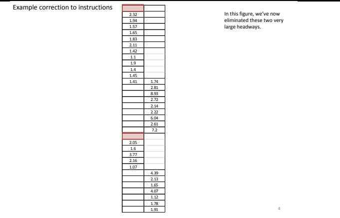
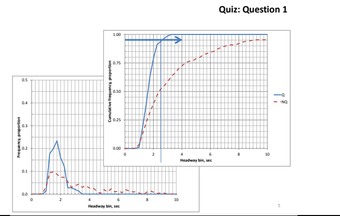
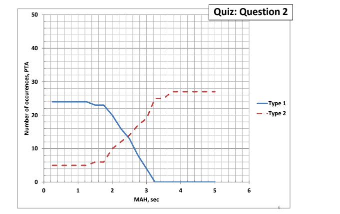
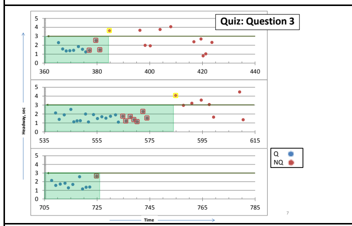
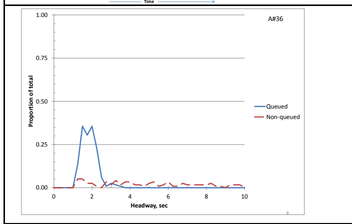
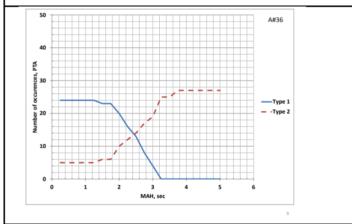
Review the results and notes from Activity #36 and the description of Activity #37.

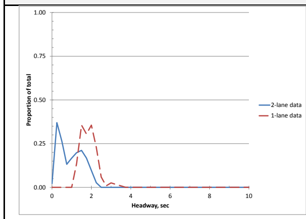
Doing the Activity (Script)

[Slides: slides37.pptx]

The following slides and script can be used as part of conducting this activity.

Slide	Text
	
	
	

Slide	Text
	
	
	
	
	
	
1. Create new tabs in Excel (from A#36 file) 2. Collect speed data 3. Headway distributions for two lane data 4. Phase termination analysis 5. Select MAH 6. Compare one lane and two lane data 7. Compute passage times 8. Observe VISSIM and collect performance data with new passage time values	

<table>
<tr><th>Slide</th><th>Text</th></tr>
<tr><td>
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<tr><td>
<table>
<tr><th>Data CP</th><th>t(enter)</th><th>t(leave)</th><th>VehNo</th><th>Type</th><th>Line</th><th>v[m/s]</th><th>a[m/s²]</th><th>Occ</th><th>Pers</th><th>tQueue</th><th>VehLength[m]</th></tr>
<tr><td>2</td><td>362.12</td><td>-1</td><td>226</td><td>100</td><td>0</td><td>3.3</td><td>3.19</td><td>0.08</td><td>1</td><td>57.8</td><td>4.76</td></tr>
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<tr><td>1</td><td>-1</td><td>363.12</td><td>224</td><td>100</td><td>0</td><td>5.7</td><td>2.51</td><td>0.02</td><td>1</td><td>61.1</td><td>4.11</td></tr>
<tr><td>2</td><td>-1</td><td>363.11</td><td>226</td><td>100</td><td>0</td><td>6.3</td><td>2.85</td><td>0.01</td><td>1</td><td>57.8</td><td>4.76</td></tr>
<tr><td>2</td><td>364.58</td><td>-1</td><td>231</td><td>100</td><td>0</td><td>7.1</td><td>2.75</td><td>0.02</td><td>1</td><td>50.8</td><td>4.55</td></tr>
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<tr><td>1</td><td>-1</td><td>365.4</td><td>233</td><td>100</td><td>0</td><td>7.2</td><td>1.88</td><td>0</td><td>1</td><td>47.4</td><td>4.55</td></tr>
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<tr><td>2</td><td>-1</td><td>366.84</td><td>257</td><td>100</td><td>0</td><td>10.6</td><td>2.67</td><td>0.04</td><td>1</td><td>18.1</td><td>4.61</td></tr>
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<tr><td>1</td><td>367.95</td><td>-1</td><td>247</td><td>100</td><td>0</td><td>10.7</td><td>2.64</td><td>0.05</td><td>1</td><td>29</td><td>4.11</td></tr>
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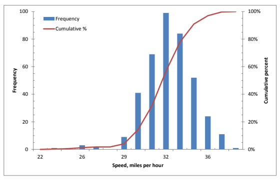
2.24 → mi/hr
12</td><td></td></tr>
<tr><td>

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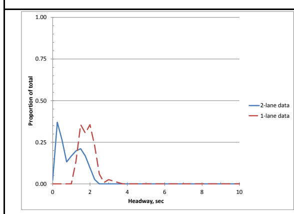
<tr><td>
</td><td></td></tr>
<tr><td>
<table>
<tr><th></th><th colspan="2">Delay (sec/veh)</th></tr>
<tr><th>Movement</th><th>A28</th><th>A37</th></tr>
<tr><td>NB</td><td>21</td><td>20</td></tr>
<tr><td>SB</td><td>5</td><td>5</td></tr>
<tr><td>EB</td><td>17</td><td>15</td></tr>
<tr><td>WB</td><td>9</td><td>9</td></tr>
</table></td><td></td></tr>
</table>

Solutions
[Excel file with solutions data: solutions37.pptx]

Included here are:

- Task data results in Excel file
- Slides for class discussion on quiz.

Task results

Task 1 asks students to use the 50th percentile of speed, maximum allowable headway and vehicle length from the previous activity to calculate the passage time for 6, 22, and 66 ft. detector lengths which can be seen in Table 5. Simulation results can be seen in Table 6. The 66 ft. detector was selected.

Table 5: Detection zone length and passage time

Detector Length (ft)	Passage Time (sec)
6	2.2
22	1.8
66	0.9

Table 6: Detector length and passage time simulation results

	6 ft detector		22 ft detector		66 ft detector	
Movement	Queue (ft)	Delay (sec/veh)	Queue (ft)	Delay (sec/veh)	Queue (ft)	Delay (sec/veh)
EBTH	13.6	5.6	13	5.4	10.1	4.7
EBLT	40.4	23.2	39.8	22.9	40.3	23.1
WBTH	40	15.5	40.6	16.1	35.2	14.7
WBRT	6.4	12.5	7.3	13.8	5.9	11.5
SBRT	31.4	23.1	28.8	24.3	22.9	19.8
SBLT	16.7	20.8	16.1	19.4	17.4	20.6
Intersection	25.7	13.5	24.9	13.5	22.1	12.5

Task 2 asks students to run a VISSIM simulation using 5, 10, and 15 second minimum green time and determine the unused green time. To complete an unused green time analysis, each cycle is observed to determine the duration that a phase remains green after serving the last queued vehicle. For each cycle, the number of queued vehicles which were not served before the phase terminates or the number of non-queued vehicles which were after the queue was fully served should be recorded. Error! Reference source not found. shows the frequency of unused green time for each minimum green time. A minimum green time of 5 seconds was selected.

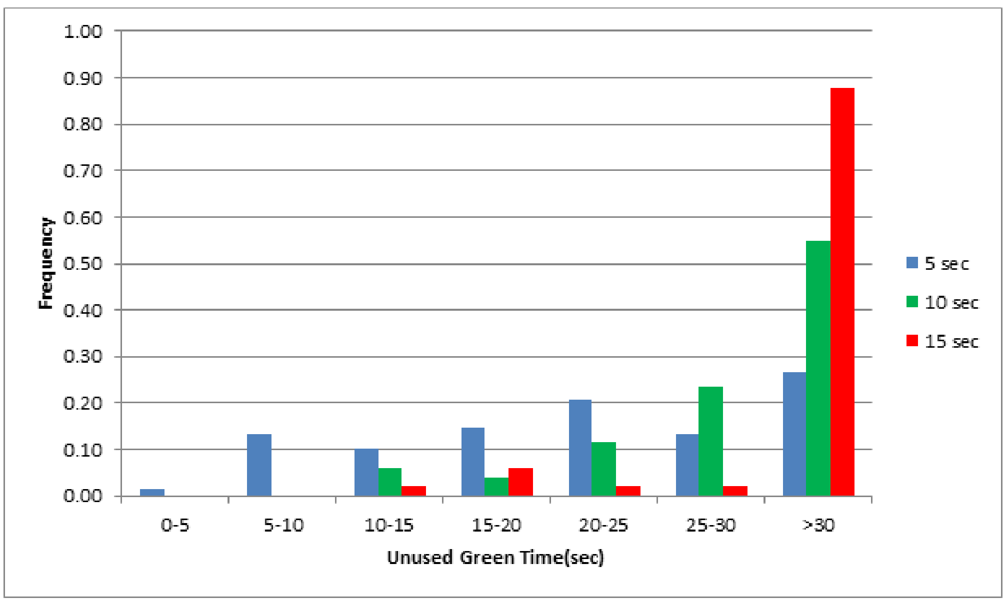


Figure 4. Unused green time

Quiz/Discussion to be used after A36/A37

<table>
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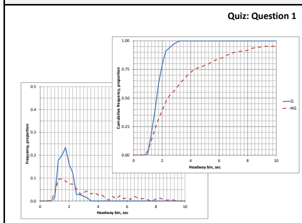
<td>
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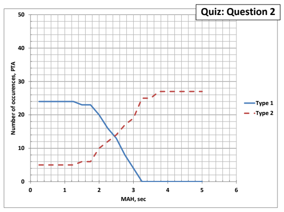
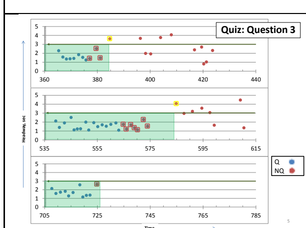
<td>
Q1. These two charts show distributions for headways both in queue at the start of green and for the period after the queue has cleared.

List two points that you can make about the characteristics of vehicles that were a part of the queue (Q) as well as vehicles that weren’t part of the queue (NQ)
If your objective is to serve 95% of the vehicles in the queue, what would you set the MAH?

A1: The two charts show (1) the frequency distribution and (2) the cumulative frequency diagram for two headway measurements: those taken during a departing queue (Q) and those taken after the queue has cleared (NQ). For the queued vehicles (Q), we expect the frequency distribution to show values centered on a mean that is near the ideal saturation headway (here, 1.7 seconds) and the range is narrow (0.9 to 3.2 seconds). For the non-queued vehicles (NQ), the range is larger, from 0.6 to 18.5 seconds; the mean is higher (3.5 seconds) and the standard deviation is much higher.
Here are some example comparisons between the two distributions:
<table>
<tr><th>Statistics</th><th>Q Vehicles</th><th>NQ Vehicles</th></tr>
<tr><td>Mean</td><td>1.7</td><td>3.5</td></tr>
<tr><td>Min-Max</td><td>0.9 – 3.2</td><td>0.6 – 18.5</td></tr>
<tr><td>Standard deviation</td><td>0.5</td><td>2.8</td></tr>
</table>
Example points:

Queued vehicles are in a pretty narrowly defined distribution while the non-queued vehicles have a much more dispersed distribution.
There are short headways in the NQ distribution, mimicking what we would think are Q vehicles.

If the desire is to make sure that 95 percent of the vehicles in the queue are served, we could use the cumulative frequency distribution to make this determination. This results in a headway of 2.5 seconds: or, 95 percent of the headways are less than 2.5 seconds.
</td>
</tr>
</table>

Slide	Text
	Q2. This chart shows results from a phase termination analysis. • Define a phase termination analysis. • List the steps in a phase termination analysis. • Describe the results from a phase termination analysis shown in this figure. • Using these data, what value of MAH would you recommend and why? A2: [From page 206 of text] A phase termination analysis is a tool that looks at the headway data generated by a simulation model from a stream of vehicles departing from an intersection, and, given a value of MAH, classifies each phase termination into one of three types. • Type 1: when not all of the initial queue is served • Type 2: An efficient extension of green • Type 3: Phase terminations just after queue clears Following are the steps in a phase termination analysis: • Collect headway data from a simulation with a longer than normal passage time and volumes such that queues of ten to fifteen vehicles form during red. • Separate the headway data into two columns, one for queued vehicles and the other for non-queued vehicles. • Superimpose a MAH to show when each phase would end based on the headway data and the assumed MAH • Determine the number of Type 1 and 2 terminations The chart shows the number of Type 1 and Type 2 terminations for a range of values of MAH. If we select MAH to be 1.8 seconds or less, we are highly likely to end the phase too early (Type 1). If we select the MAH to be 3.4 seconds or more, we are highly likely to extend the phase too long (Type 2). But what we don't want to do is to balance these two types (which would occur if we set MAH = 2.4 seconds). It is usually more desirable to have fewer type 1 terminations so we would select a MAH in the range 2.8 seconds. We would also verify this selection in the simulation to test the operation of the intersection, using other parameters such as delay.
	Q3. This chart shows a graphical representation of a phase termination analysis. Describe what is included in this chart and what it tells you about the MAH. A3: This chart shows, for three phases, the headways for Q (blue)

Slide	Text
	and NQ (red) vehicles. Superimposed is a MAH of 3 seconds. The resulting termination time (shown with the yellow square around the headway that caused the termination) is shown, with the resulting green time duration also shown as the shaded green rectangles. In each of these three cases, there are NQ vehicles that are served, shown by the red dots surrounded by red squares. We can conclude that a three second MAH is probably too long for the conditions illustrated here.

Using Activity #38: Actuated Traffic Control Processes (In Practice)

Overview

The reading assignment is normally done as homework.

Options for Use

- 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

1. Review the relevant sections of the Traffic Signal Timing Manual.

Doing the Activity (Script)

1. 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.
2. Invite them to consider the CTQ and their answers.
3. Ask for answers and discussions for selected questions.
4. 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.
5. There is a "in my practice" section, a short note from a practitioner.

Solution

Answers to Questions

1. Describe the differences between your selected passage time and the value ranges described in the Traffic Signal Timing Manual