DEVELOPMENT OF TRAFFIC SIGNAL OPERATIONS EDUCATIONAL MATERIALS

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The traffic signal controller is one of the most ubiquitous and important components of our nation's transportation system. About two-thirds of all miles driven each year by U.S. motorists are on roadways controlled by traffic signals. In some urban areas, signals at busy intersections control the movement of more than 100,000 vehicles per day [Paulson, 2002].

However, most transportation engineers receive little if any education on traffic controllers, how they work, and how one designs a signal timing plan that takes advantage of all of the intricacies of the traffic controller-detector system. This project takes a first step to alleviate this problem by developing materials on traffic signal operations and timing that can be used to educate university students and practicing traffic engineers about the major components of the traffic control system.

This work includes the role of experts in identifying and documenting knowledge, a set of interviews conducted with experts in traffic signal operations, an assessment of the problems with current transportation engineering textbooks, the need for case studies as part of the engineering education process, and the need for materials that present the basic elements of traffic signal operations.</td></tr>
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Contents

1. Introduction

The traffic signal controller is one of the most ubiquitous and important components of our nation's transportation system. About two-thirds of all miles driven each year by U.S. motorists are on roadways controlled by traffic signals. In some urban areas, signals at busy intersections control the movement of more than 100,000 vehicles per day [Paulson, 2002].

However, most transportation engineers receive little if any education on traffic controllers, how they work, and how one designs a signal timing plan that takes advantage of all of the intricacies of the traffic controller-detector system. And despite the importance of the signal timing plan to the successful operation of urban arterials, the design, implementation, and maintenance of most signal timing plans are the responsibility of a technician reporting to an engineer. The latter often does not understand or appreciate the subtleties of traffic controller operations, while the former does not usually have the system perspective that is so fundamental to the education of an engineer.

This project takes a first step in helping to alleviate this problem. My primary objective was to develop materials on traffic signal operations and timing that could be used to educate university students and practicing traffic engineers about the major components of the traffic control system. This report summarizes the work I have completed to achieve this objective.

This work is divided into four parts.

- Section 2 of the report describes the role of experts in identifying and documenting knowledge. The section also describes a set of interviews that I conducted with seven experts, each with significant field experience in traffic signal operations. This knowledge base sets the stage for the case studies that are described later in this report.
- Section 3 describes an assessment of the problems with current transportation engineering textbooks and describes the need for case studies as part of the engineering education process. Next, a summary of what should be included in traffic signal timing case studies is presented. Finally, the section presents a summary of the case studies that I gathered that can be used for classroom purposes.
- Section 4 describes the need for materials that present the basic elements of traffic signal operations. The section also presents the text and web site that I have assembled and designed to meet this need.
- Section 5 presents a summary and conclusions from this study. The section also describes a new study recently funded by the Federal Highway Administration that will develop a set of laboratory exercises designed to educate practicing engineers and engineering students on traffic signal timing.

This work was funded in part from four University Transportation Centers Program projects (KLK230, KLK239, KLK204, and KLK213 under Grant DTRS98-G-0027) and I gratefully acknowledge this support in completing this work.

2. Interviews with Experts

This section describes the role of experts in identifying and documenting knowledge. The section also describes a set of interviews that I conducted with seven experts, each with significant field experience in traffic signal operations. This knowledge base sets the stage for the case studies that are described later in this report.

2.1 Experts and knowledge

Transportation engineers who regularly prepare signal timing design plans have a vast amount of knowledge on traffic flow, geometric design, and traffic signal controllers, and the relationship between these three kinds of data. While they are sometimes able to communicate how they approach a given problem, what factors they consider in solving the problem, and the process that they go through in this solution, experts often don't (or maybe can't) clearly articulate this process to a new or young engineer. Certainly as experienced and talented engineers retire, the profession often loses this valuable (an often undocumented) experience.

There exists some research on the concept of the knowledge base, how it is accumulated by experts, and how this knowledge could be more formally structured so that it can be passed on to others Schön[1], for example, asks "What is the kind of knowing in which component practitioners engage? How is professional knowing like and unlike the kinds of knowledge presented in academic textbooks . . .?" He notes that

> "the study of reflection-in-action is critically important. The dilemma of rigor or relevance may be dissolved if we can develop an epistemology of practice which places technical problem solving within a broader context of reflective inquiry, shows how reflection-in-action may be rigorous in its own right, and links the art of practice in uncertainty and uniqueness to the scientist's art of research. We may thereby increase the legitimacy of reflection-in-action and encourage its broader, deeper, and more rigorous use".

Engineering educator Don Elger noted that the major problem is that experts usually "just do it." Because they are not very aware of how they are proceeding, it is difficult to uncover the process that they use in design.

> "The most common way to reveal the expert process is to give experts a discipline specific task and then have them talk aloud as they work their way through this problem. One does this with many experts and then reviews the transcripts and codes then in order to reveal the common patterns that appear (i.e. what is that most experts have in common)."[2]

Another engineering educator notes that this kind of problem solving involves knowledge, mental activities and creativity.

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[1] Donald A. Schön, "The Reflective Practitioner: How Professionals Think in Action", Basic Books, 1983.
[2] Telephone discussion and email exchange with Dr. Donald Elger, Professor of Mechanical Engineering, University of Idaho, 28 January 2004.

"I think part of what we try to do in engineering curricula is to help people learn how to approach problems and to perform the different mental activities in order to become effective problem solvers. The logical, left-brain parts of this we do very well, I think, but I think we don't do so well with the right-brain, integrative, creative, holistic types of activities. That's where we get into the critical thinking/reflective judgment things. And those can't be measured very easily!

"Some characteristics of expert problem solvers are that they think in terms of patterns of information, rather than discrete, individual factoids; they possess excellent domain knowledge, that is, knowledge of the field of the problem, as well as knowledge about problem solving approaches (often tacit rather than explicit); they have a "can do" attitude, are creative, and are not easily discouraged; and they use a wide range of heuristics.

"Now, regarding the main thrust of your question, how do you understand and document the process that experts use... I can't claim to be an expert on this. In William Perry's work, he trained interviewers to ask very open-ended questions, recorded the conversations with the students, then analyzed and interpreted their comments and drew inferences about their mental activities and thinking. I've tried to use a metaphysical kind of approach in which students think about their thinking. In other words, rather than my inferring how their minds are working, I've tried to get them to be aware of and to think about the mental processes they go through when working on problems. In most cases, I don't think they even are aware that they can do this, so it helps just to point it out as a possibility. Of course, many aren't interested. They just "want to build things."[3]

2.2 Interviews

Clearly, we need to better understand the process by which transportation engineering professionals think about the signal timing design process, both explicitly and implicitly. To assist in this process, I conducted interviews with seven transportation engineering professionals in Boise, Idaho, each of whom have a significant amount of experience with traffic signal timing design and operations. See Table 1. Each interview was digitally recorded. These interviews have been transcribed and will be published as a separate report.

Table 1 List of Subject Interviews

Name	Organization
Jim Pline	Pline Engineering
Mike Boydstun	Ada County Highway District
Jim Larsen	Ada County Highway District
John Ringert	Kittelson and Associates
Scott Jones	Six Mile Engineering
Andy Daleiden	Kittelson and Associates
Lee Rodegerdts	Kittelson and Associates

[3] Email exchange with Dr. Roger Ely, Associate Professor of Bioengineering, Oregon State University, 28 January 2004.

Table 2 shows the instructions that were given to each professional who was interviewed. Figure 1 shows the intersection aerial photograph that was shown to each of the interviewees. Each interview took from 30 to 45 minutes.

Table 2 Interview Instructions and Questions

The City of Moscow and the Idaho Transportation Department have prepared a design for a new traffic signal to be installed at the intersection of Sixth and Deakin, located in Moscow, Idaho. The intersection is currently controlled by a stop sign on the minor (Deakin Street) approach. The new intersection design is shown in the figure below. Sixth Street provides access to the University of Idaho, while Deakin Street provides access to both the University and adjacent residential areas. Sixth Street has one through lane on each approach, with a left turn lane for westbound traffic and a right turn lane for eastbound traffic. Deakin Street has two turn lanes, one for left turning (westbound) traffic and the other for right turning (eastbound) traffic. The PM peak hour traffic flow rates are shown in the figure below.

Your objective is to complete a signal timing design for this intersection.

You will work independently on your design. I will document the work that you do, using both the voice recorder and notes that I take as you complete your work. I would ask that you describe orally as much of your thinking as possible as you do your work. I also ask that you write down your work, including all of your steps, assumptions, and conclusions. I may ask you questions to clarify your work but I will not guide your work in any way.

Questions to designer:

- What information do you need in order to design the timing plan for this signalized intersection?
- Briefly describe what your final output will be. [or, What is the normal form of the output from this design; what parameters do you include in this design]
- What are the timing parameters that you will produce? [how do you determine the parameters? which are computed using design guidelines or standards, and which are produced using analysis tools or models?]
- What is the proper sequencing of phases for this intersection? [How do you determine the sequence? What options do you consider?]
- What MOEs do you use to measure the performance of the intersection?
- What models or tools do you use to produce these MOEs?
- Describe the process or steps that you will go through to produce your timing parameters.
- What other factors should you consider: pedestrian phasing, other controller settings, volume variations during the day, detector settings/issues?

Figure 1. Sixth and Deakin

3. Case Studies

This section describes an assessment of the problems with current transportation engineering textbooks and describes the need for case studies as part of the engineering education process. Next, a summary of what should be included in traffic signal timing case studies is presented. Finally, the section presents a summary data that I have gathered for the case studies.

3.1 The need for case studies

The current civil engineering curriculum is not meeting the need for broadly educated, technically well-trained transportation engineers who have the critical thinking and problem solving skills required for today's work environment. The problem can be traced to two sources, the way we teach engineering today and the way transportation engineering fits into the civil engineering curriculum at most U.S. universities.

The challenges in engineering education are well known. Wales, Nardi, and Stager[4] note that most engineering curricula emphasize covering copious bodies of knowledge rather than concentrating on teaching the thinking skills needed for complex problem solving, a primary goal of engineering education. The idea persists that knowledge must be acquired first and that its application to reasoning and problem solving can happen later[5]. In a good faith effort to teach engineering, instructors attempt to cover encyclopedic textbooks in the short span of a quarter or semester. This model of teaching is an old one, assuming that knowledge can be simply transmitted to a receiver. The students, in a good-faith effort to learn, end up "learning nothing about everything" and begin to hone their dead-end strategies in order to survive the courses[6]. In contrast, effective educators focus on student mastery of content through high-level thinking skills (such as application, analysis, synthesis and evaluation) resulting in greater acquisition of content and development of thinking skills[7].

The challenge of integrating transportation engineering into the civil engineering curriculum has been less well documented. Students enter their first transportation engineering course after two or three years of immersion in a mechanics-based curriculum, often with a preconceived notion that civil engineering means structural engineering. They often complain that transportation

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[4] Wales, C. E., A. H. Nardi, and R. A. Stager, "Thinking Skills: Making a Choice." *Center for Guided Design Newsletter*. Morgantown, WV: West Virginia University, 1987.
Wales, C. E., A. H. Nardi, and R. A. Stager, "Teaching Thinking Skills: Research Supports Experience." *Center for Guided Design Newsletter*, Morgantown, WV: West Virginia University, 1989

[5] Resnik, L. B., *Education and Learning to Think*. Washington, DC: National Academy Press, 1987.

[6] Wales, C. E., "Thinking about Thinking about Thinking," *Center for Guided Design Newsletter*. Morgantown, WV: West Virginia University, Dec. 1989, p.9.

[7] Resnik, L. B., *Education and Learning to Think*. Washington, DC: National Academy Press, 1987.
McDermott, L. C., "How we teach and how students learn- a mismatch?" *American Journal of Physics* 61(4): 1993. Available at http://unr.edu/homepage/jcannon/ejse/mcdermott.html, accessed 12 March 2007.
Leonard, W. J., W. J. Gerace, R. J. Dufresne, & J. P. Mestre, "Concept-based problem solving," U. Mass, Dept. Physics and Sci. Reason. Inst, 1999 http://umperg.physics.umass.edu/gemsFolder/umperg2/umperg_1999_12.pdf. accessed 2 June 2004,
Mestre, J. P. (1994) "Cognitive Aspects of Learning and Teaching Science," *Teacher Enhancement for Elementary and Secondary Science and Mathematics*: *Status, Issues and Problems,* Ed. S. J. Fitzsimmons & L. C. Kerpelman. Washington, D.C.: National Science Foundation, pp. 3-1, 3-53. (NSF 94-80).

seems irrelevant to the rest of their civil engineering education. This perspective greatly hinders their interest in and motivation toward courses in the transportation area[8].

In addition, the textbooks available for transportation engineering courses encourage a gap between methods and desired outcomes. Many problems in these textbooks are designed either to illustrate the topics covered or to give students practice and reinforcement in those same areas. To quantify this problem, I conducted an assessment of three introductory transportation engineering textbooks. The assessment included a review of the examples and problems devoted to traffic signal timing and operations.

When these texts are assessed using Bloom's validated taxonomy of educational objectives[9], the findings are not encouraging (see Table 3). While the examples and problems in two of the texts require students to complete a significant number of sequential calculations (in contrast with the third text that presented primarily only single equation calculations), the problems do not tie closely with real world situations. Most of the problems are narrowly based, have simplistic solutions, and only require students to substitute numbers into equations to produce single and simplistic "correct" answers. Interpretation of the results, which is so important in engineering design, is not addressed. Students using these texts learn little of the problems facing practicing traffic engineers and even less about the way transportation design is accomplished.

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[8] This largely negative attitude greatly contrasts with the overwhelmingly positive comments of both instructors and students who have participated in the innovative Traffic Signal Summer Workshop held each year at the University of Idaho since 2000. The results of this workshop are reported in Kyte, Abdel-Rahim, and Lines, "Traffic Signal Operations Education through Hands-On Experience: Lessons Learned from a Workshop Prototype" in *Transportation Research Record* 1848, Transportation Research Board, 2003.

[9] Anderson, Lorin W. and David R. Krathwohl, Ed. *A Taxonomy for Learning, Teaching, and Assessing*. Abridged Edition. Addison Wesley Longman, 2001.

Table 3 Evaluation of Textbook Material

		Textbook #1		Textbook #2		Textbook #3	
		Example	Problem	Example	Problem	Example	Problem
Number		8	14	7	23	4	34
Knowledge type	% factual	0	0	0	0	0	0
	% conceptual	0	0	14	26	0	0
	% procedural	100	100	86	74	100	100
Calculation complexity	% none	0	50	0	26	0	3
	% single	75	7	29	4	100	30
	% multiple	25	43	71	70	0	67
Judgment level	% none	62	14	0	30	25	12
	% simple	38	86	71	0	50	18
	% complex	0	0	29	70	25	70

Notes: *Example* refers to worked problems included in chapter texts. *Problem* refers to end-of-chapter problems solved by students. C*omplexity of calculation* is based on the number of calculations needed to solve a problem. *Judgment level* assesses whether or not students need to interpret answers or judge the way the numeric solution is used within a standard or external criterion.

3.2 A framework for case studies

A framework for case studies has been developed as part of this study. This framework includes the components that must be included in the case studies and the design process that should be followed in the case studies. This framework is presented in this sub-section.

The case studies should address a range of technical and other issues relating to traffic signal systems and are based on real world situations. They should illustrate the often conflicting needs of varying constituents that exist in everyday practice.

Each problem should utilize a learning process defined by a set of educational objectives and include a well-defined set of computations and problems and a concluding interpretative and assessment focus. The problems should be complex (requiring integration of knowledge) and allow for multiple solutions and multiple solution paths. The problems should allow for hands-on experiences with models and equipment, including commonly used public domain software tools and traffic control equipment.

The case studies should include components that replicate the stages of the analysis and design process (see Figure 2). The shaded boxes in the figure illustrate the progression of one complete thread in this process.

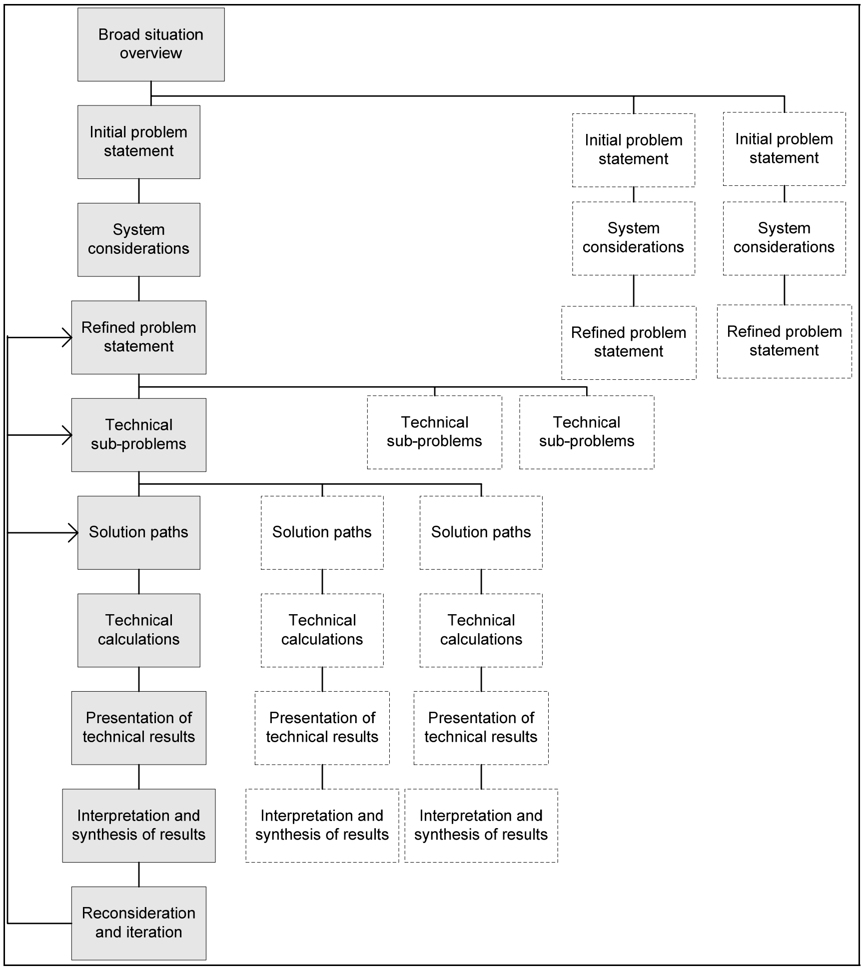

Figure 2. Components of case studies

1. Each problem will begin with a description of the signalized intersection under study, the surrounding transportation network (especially adjacent intersections) and some of the conditions present at this facility (volumes, intersection layout, control devices).
2. Several problem statements will be provided for each signalized intersection. These statements will present a problem that is faced either by a local jurisdiction, a state agency, or a consultant (from the political or citizen perspective rather than from the perspective of the transportation engineer). These statements will provide a range of problems that can be used by the instructor.
3. For each of the initial problem statements there will be a discussion of broad, system considerations. These considerations will be presented in a way that encourages students to identify and consider the wider ramifications of the problem and to see other issues that might affect the definition of the problem. These considerations will lead to a refined problem statement.

4. For each refined problem statement, a set of technical sub-problems will be provided. Each sub-problem will be a well-defined technical statement of a problem to be solved by the student or team of students using a standard engineering method or model.
5. Each technical sub-problem will have multiple solution paths, each with technical calculations, presentation of technical results, and interpretation and synthesis of results. Materials will be developed for each of these components, providing the instructors with the support needed to work with their students. Because of its importance, special consideration will be given to materials that the instructors need to encourage student interpretation and synthesis of the results.
6. Reconsideration and iteration will encourage the student to modify the problem statement, the technical sub-problem, or the solution path based on what they learn from their initial solution.

To develop the educational objectives for this project, I used Bloom's revised taxonomy matrix[10], covering both the knowledge dimension and the cognitive process dimension. This matrix, an example of which is shown in Table 4, is a powerful means of transforming the ad hoc process of developing objectives into a formal structure.

Table 4 Example Learning Objectives

Cognitive process dimension	Knowledge dimension	Example learning objective
1. Knowledge	A. Factual	• Define timing parameters for an actuated traffic signal
2. Comprehension	B. Conceptual	• Document operation of actuated traffic controller
5. Application/Analysis	C. Procedural	• Design (optimize) phase patterns
6. Evaluation	C. Procedural	• Evaluate intersection performance

3.2.1 Signal timing design process

In order to provide a context for the case studies, a design process is proposed.
Figure 3 illustrates the proposed process. The column on the left shows the questions that need to be answered, while the column on the right describes the information required or the tools that may be used.

[10] Anderson, Lorin W. and David R. Krathwohl, ed. *A Taxonomy for Learning, Teaching, and Assessing*. Abridged Edition. Addison Wesley Longman, Inc. 2001.

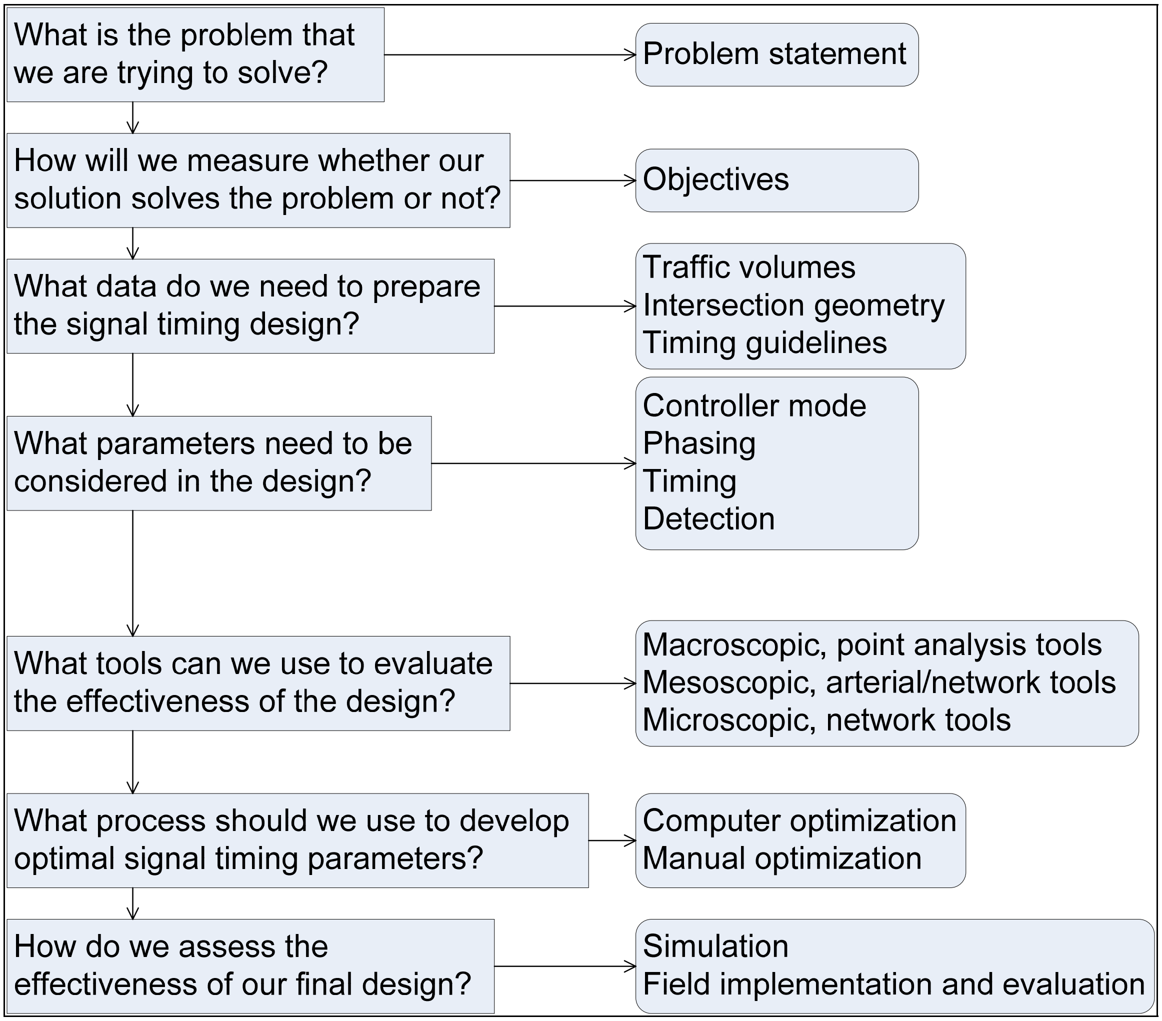

Figure 3. Signal timing design process.

A more detailed list of the components that must be considered during the design process is shown in
Figure 4. The components include controller mode, phasing, timing, and detection. Each component includes a set of attributes. For example, the controller mode includes two attributes: responsiveness (actuated or fixed time) and coordination (coordinated or isolated).

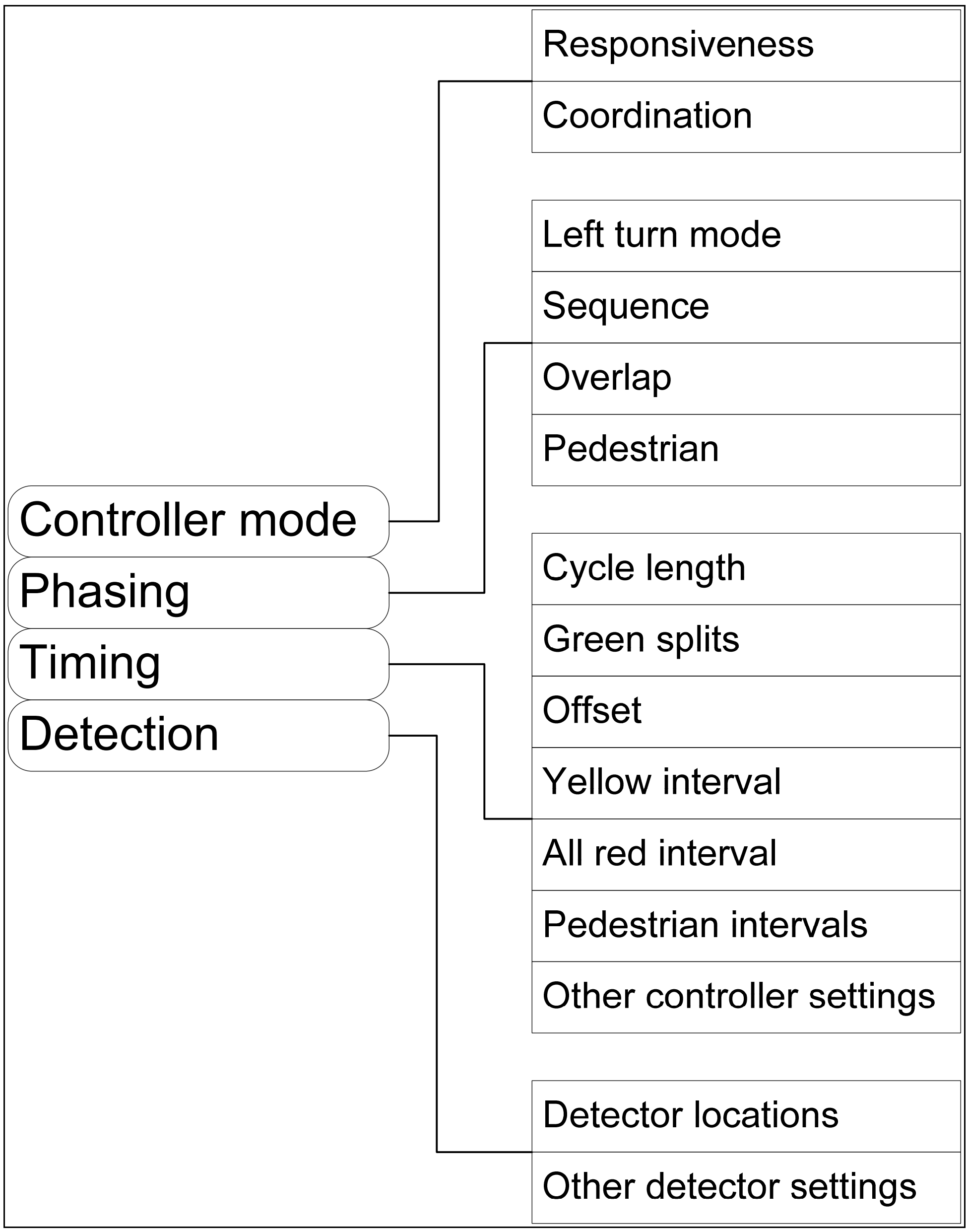

Figure 4. Traffic controller timing components.

3.2.2 Case study locations

Information has been collected for several sites that will serve as case studies for this project. These sites are listed in Table 5. Photographs of the sites are shown in **Figure 5** through Figure 10. Detailed information has been collected for the first three sites, 6th/Deakin and the two I84 sites.

Table 5 Case Study Sites

Intersection	City/State	Data available	Figure
6th/Deakin	Moscow, ID	Aerial photographs Traffic volumes	Figure 5
I84-Exit 29 interchange	Caldwell, ID	Aerial photographs Traffic volumes Design plans Traffic analysis results	Figure **6**
I84-Garrity interchange	Caldwell, ID	Aerial photographs Traffic volumes Design plans Traffic analysis results	Figure 7
Chindon/Linder	Ada County, ID	Aerial photographs Photographs	Figure 8
Cindon/Star	Ada County, ID	Aerial photographs Photographs	Figure 9
Gary Lane/Hill Rd	Boise, ID	Aerial photographs Photographs	Figure 10

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Figure 5. Sixth and Deakin.

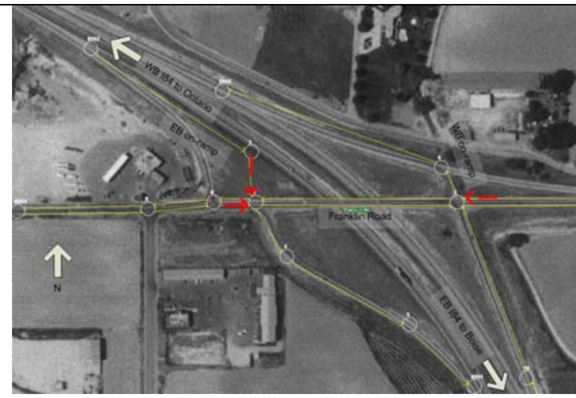


Figure 6. I84 exit 29,Caldwell.

Figure 7. I84 Garrity interchange.

Figure 8. Chindon/Linder.

Figure 9. Chindon/Star

Figure 10. Gary/Hill.

4. Text and Web Site

This section describes the need for materials that present the basic elements of traffic signal operations. The section also presents the text and web site that I have assembled and designed to meet this need.

4.1 Topic outline

In order for students to complete the case studies, a set of preparatory materials is needed. These materials provide information that is needed for a student to complete a signal timing design. The following topics are included as the outline for these materials.

Table 6 Topic Outline

1. Overview
2. Traffic operations and control - approach
3. Traffic operations and control -intersection
4. Detection and timing parameters
5. Vehicle clearance period
6. Pedestrian phasing
7. Other detection concepts
8. Rings and phase sequencing
9. Left turn phasing
10. Maximum green time/cycle length
11. Transit priority
12. Preemption
13. Other controller functions
14. Signal timing design issues - approach
15. Signal timing design issues - intersection

4.2 Web site layout/format

An initial web layout for these materials has been prepared and is available at the following link:

http://www.webs1.uidaho.edu/trafficsignalcontrol/

Several points should be noted about this initial design:

- Figure 11 shows the basic page layout, including the navigation tools, the text, the supporting graphics, the chapter title, and the page number.
- Figure 12 shows an example of a page that has both text and the supporting graphics for the text.
- Figure 13 shows an example of the learning objectives.

Figure 14 and

- Figure 15 shows an example of the discussion questions for students as they read the text.
- Figure 16 shows an example of the end of chapter problems.

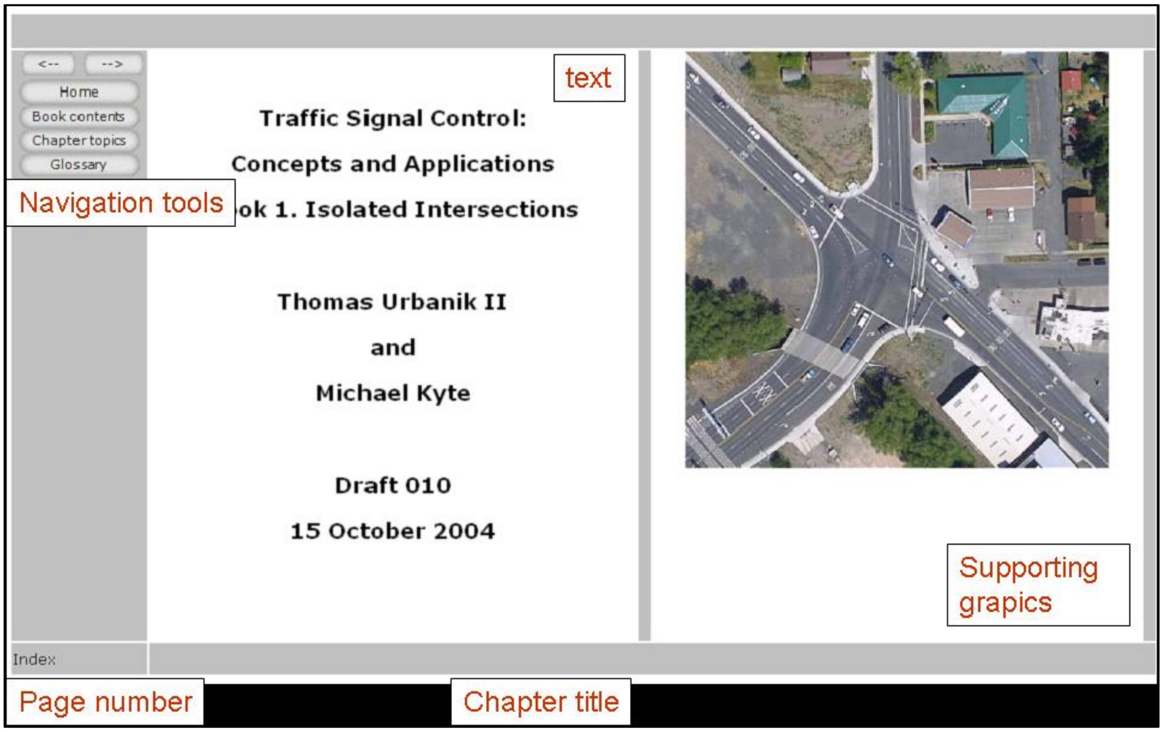


Figure 11. Design elements of web layout.

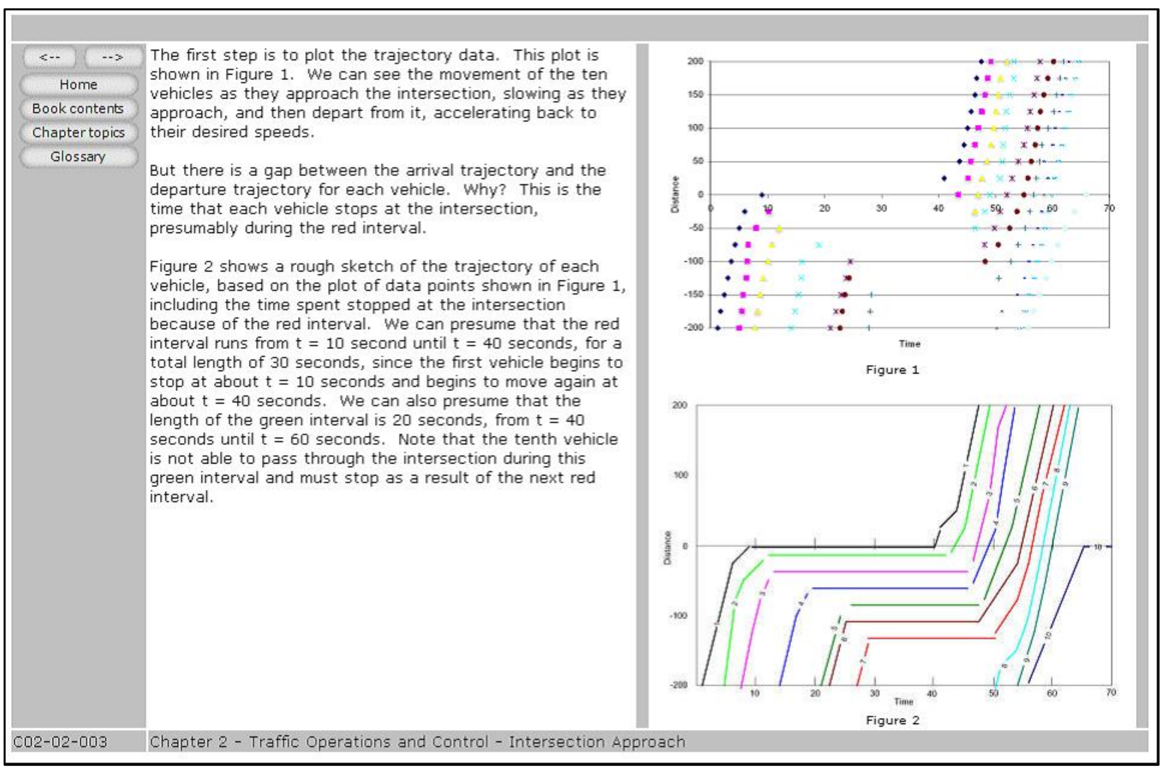
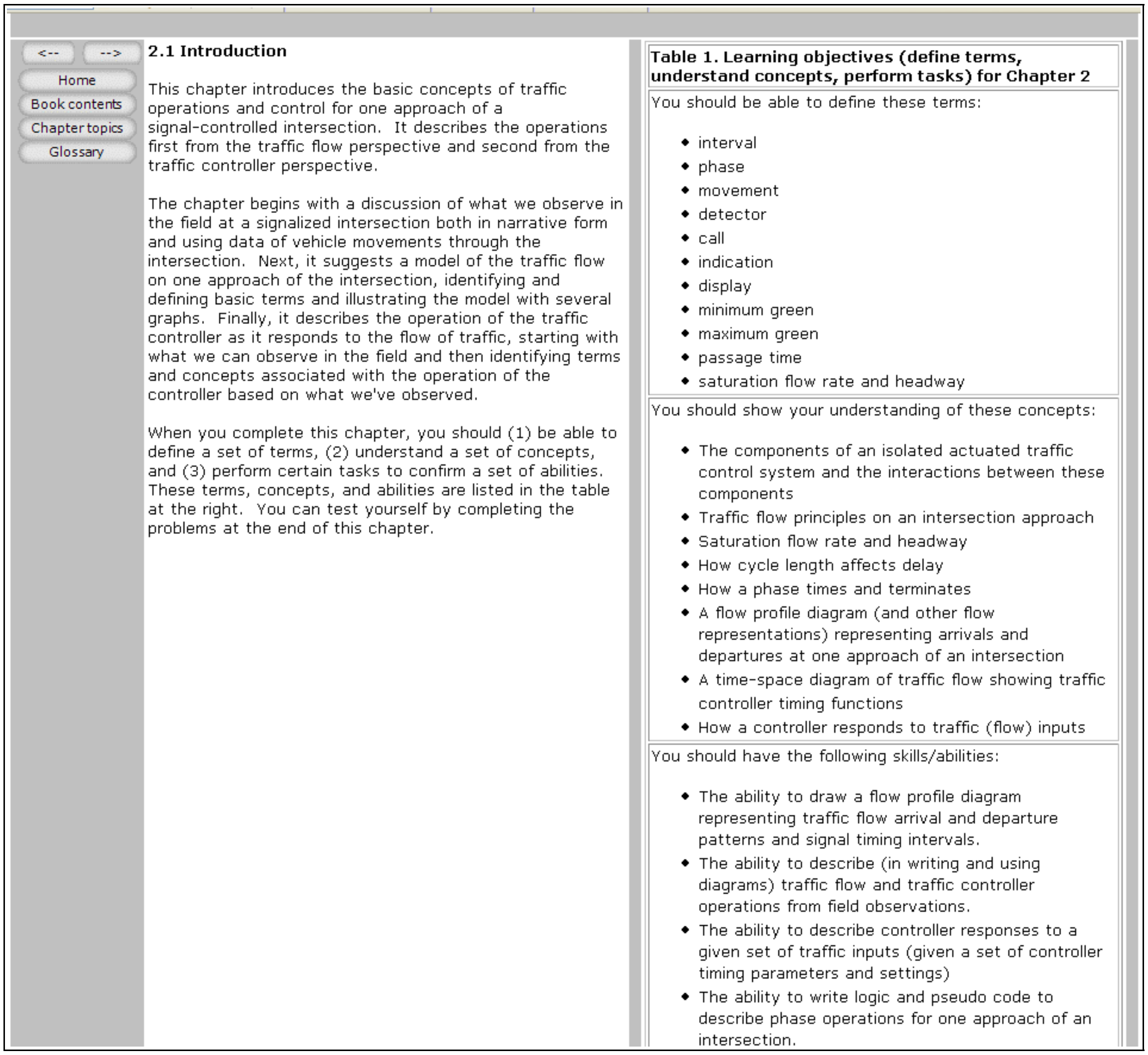


Figure 12. Text and supporting graphics.



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Home
Book contents
Chapter topics
Glossary

2.1 Introduction

This chapter introduces the basic concepts of traffic operations and control for one approach of a signal-controlled intersection. It describes the operations first from the traffic flow perspective and second from the traffic controller perspective.

The chapter begins with a discussion of what we observe in the field at a signalized intersection both in narrative form and using data of vehicle movements through the intersection. Next, it suggests a model of the traffic flow on one approach of the intersection, identifying and defining basic terms and illustrating the model with several graphs. Finally, it describes the operation of the traffic controller as it responds to the flow of traffic, starting with what we can observe in the field and then identifying terms and concepts associated with the operation of the controller based on what we've observed.

When you complete this chapter, you should (1) be able to define a set of terms, (2) understand a set of concepts, and (3) perform certain tasks to confirm a set of abilities. These terms, concepts, and abilities are listed in the table at the right. You can test yourself by completing the problems at the end of this chapter.

Table 1. Learning objectives (define terms, understand concepts, perform tasks) for Chapter 2

You should be able to define these terms:

- interval
- phase
- movement
- detector
- call
- indication
- display
- minimum green
- maximum green
- passage time
- saturation flow rate and headway

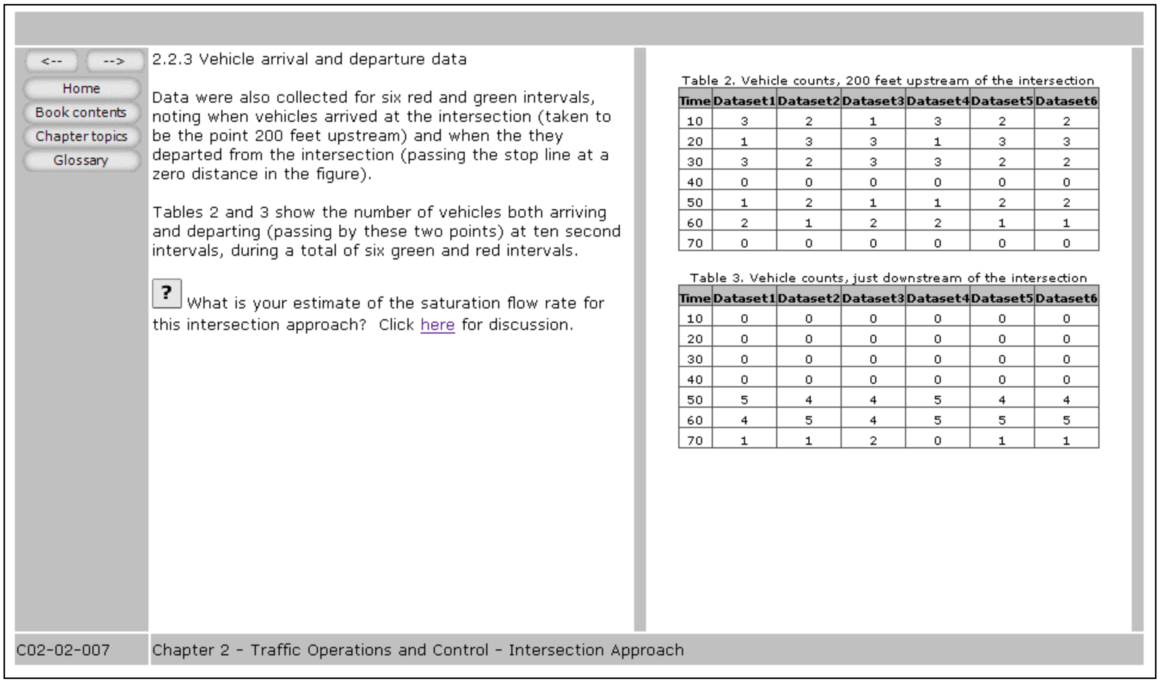
You should show your understanding of these concepts:

- The components of an isolated actuated traffic control system and the interactions between these components
- Traffic flow principles on an intersection approach
- Saturation flow rate and headway
- How cycle length affects delay
- How a phase times and terminates
- A flow profile diagram (and other flow representations) representing arrivals and departures at one approach of an intersection
- A time-space diagram of traffic flow showing traffic controller timing functions
- How a controller responds to traffic (flow) inputs

You should have the following skills/abilities:

- The ability to draw a flow profile diagram representing traffic flow arrival and departure patterns and signal timing intervals.
- The ability to describe (in writing and using diagrams) traffic flow and traffic controller operations from field observations.
- The ability to describe controller responses to a given set of traffic inputs (given a set of controller timing parameters and settings)
- The ability to write logic and pseudo code to describe phase operations for one approach of an intersection.

Figure 13. Learning objectives.



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2.2.3 Vehicle arrival and departure data

Data were also collected for six red and green intervals, noting when vehicles arrived at the intersection (taken to be the point 200 feet upstream) and when the they departed from the intersection (passing the stop line at a zero distance in the figure).

Tables 2 and 3 show the number of vehicles both arriving and departing (passing by these two points) at ten second intervals, during a total of six green and red intervals.

? What is your estimate of the saturation flow rate for this intersection approach? Click here for discussion.

Table 2. Vehicle counts, 200 feet upstream of the intersection

Time	Dataset1	Dataset2	Dataset3	Dataset4	Dataset5	Dataset6
10	3	2	1	3	2	2
20	1	3	3	1	3	3
30	3	2	3	3	2	2
40	0	0	0	0	0	0
50	1	2	1	1	2	2
60	2	1	2	2	1	1
70	0	0	0	0	0	0

Table 3. Vehicle counts, just downstream of the intersection

Time	Dataset1	Dataset2	Dataset3	Dataset4	Dataset5	Dataset6
10	0	0	0	0	0	0
20	0	0	0	0	0	0
30	0	0	0	0	0	0
40	0	0	0	0	0	0
50	5	4	4	5	4	4
60	4	5	4	5	5	5
70	1	1	2	0	1	1

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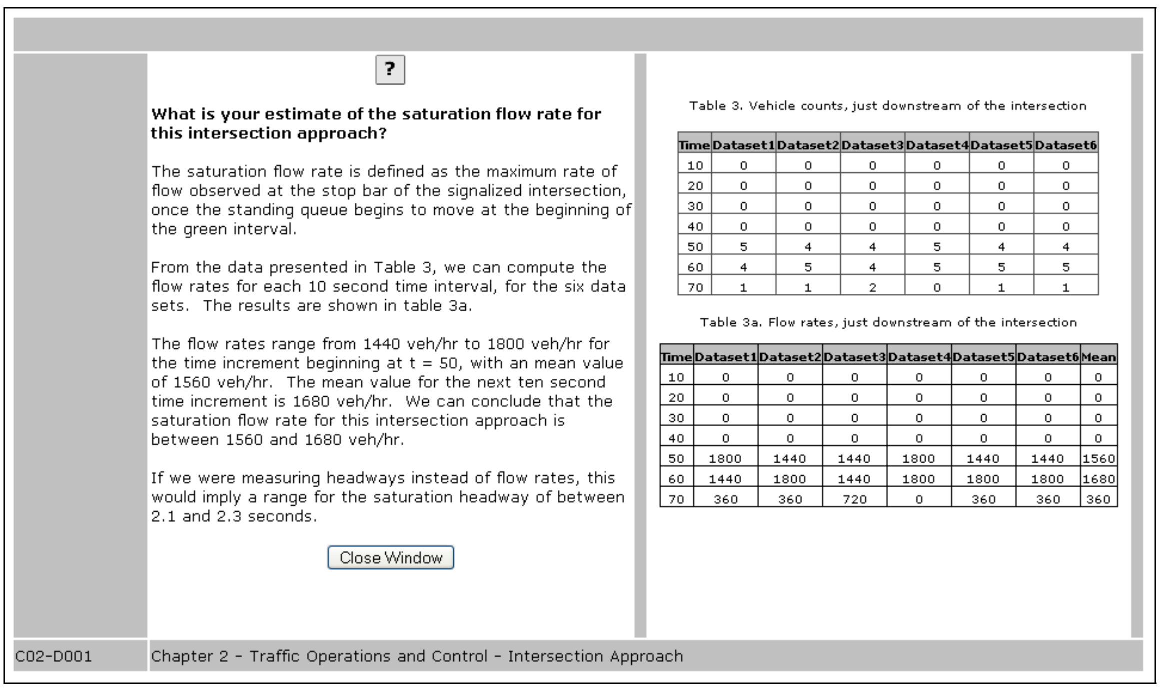
Figure 14. Example discussion question.



?

What is your estimate of the saturation flow rate for this intersection approach?

The saturation flow rate is defined as the maximum rate of flow observed at the stop bar of the signalized intersection, once the standing queue begins to move at the beginning of the green interval.

From the data presented in Table 3, we can compute the flow rates for each 10 second time interval, for the six data sets. The results are shown in table 3a.

The flow rates range from 1440 veh/hr to 1800 veh/hr for the time increment beginning at t = 50, with an mean value of 1560 veh/hr. The mean value for the next ten second time increment is 1680 veh/hr. We can conclude that the saturation flow rate for this intersection approach is between 1560 and 1680 veh/hr.

If we were measuring headways instead of flow rates, this would imply a range for the saturation headway of between 2.1 and 2.3 seconds.

Close Window

Table 3. Vehicle counts, just downstream of the intersection

Time	Dataset1	Dataset2	Dataset3	Dataset4	Dataset5	Dataset6
10	0	0	0	0	0	0
20	0	0	0	0	0	0
30	0	0	0	0	0	0
40	0	0	0	0	0	0
50	5	4	4	5	4	4
60	4	5	4	5	5	5
70	1	1	2	0	1	1

Table 3a. Flow rates, just downstream of the intersection

Time	Dataset1	Dataset2	Dataset3	Dataset4	Dataset5	Dataset6	Mean
10	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0
50	1800	1440	1440	1800	1440	1440	1560
60	1440	1800	1440	1800	1800	1800	1680
70	360	360	720	0	360	360	360

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Figure 15. Example discussion.

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2.9 Problems

1. Prepare a sketch that shows the components of the actuated traffic control system and how the interactions and relationships between each component.

2. Draw a flow profile diagram of vehicles arriving and departing at one approach of a signalized intersection, showing the related timing intervals for traffic moving on that approach. Base your diagram on the observation of two complete phases for one approach of a signalized intersection in the field.

3. Use a diagram to describe how a phase times and how it terminates. Your diagram should include reference to detector calls on both the subject phase and a conflicting phase, the minimum green time, the passage time, and the maximum green time.

4. The table on the right shows the times that detector calls are placed on the subject phase and a conflicting phase during one phase for the subject approach. Assume that the green interval begins at t = 0, and the following timing parameters:

- minimum green time = 10 seconds
- passage time = 3 seconds
- maximum green time = 20 seconds

Using a time-distance sketch, show the time evolution of the states of each of the three timers and when the phase terminates.

5. Using the traffic flow principles described in this chapter, and considering the factors that affect delay, prepare an argument that shows whether longer cycle lengths or shorter cycle lengths result in lower delay for the motorist.

Subject call	Subject call dropped	Conflicting call
1.7 4.6 7.2 9.8 12.5 17.3	2.1 4.9 7.5 10.1 12.8 17.5	4.5

Table. Detector calls for problem 4

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Figure 16. End-of-chapter problem.

4.3 Status of initial text/drafts

Initial text has been written for chapters 2 through 5. A detailed outline for these chapters is listed below. Chapter 2 has been transformed into the web layout described in the previous section of this report. The other chapters will be completed during the spring semester 2005 as part of CE 572, Applied Intersection Operations, to be offered at the University of Idaho.

Chapter 2 – Traffic Operations and control on an intersection approach
2.1 Introduction
2.2 Observer narrative and field data – traffic flow
2.2.1 Narrative
2.2.2 Vehicle trajectory data
2.2.3 Vehicle arrival and departure data
2.3 Observer narrative and field data - pedestrian flow
2.4 Models of what we've observed – vehicular traffic flow
2.4.1 Overview
2.4.2 Vehicle trajectory model
2.4.3 Flow rate model
2.4.4 Cumulative vehicle model
2.4.5 Queue model
2.5 Models of what we've observed – pedestrian flow
2.6 Observer narrative and field data – the controller
2.6.1 Narrative
2.6.2 Field data
2.7 Controller operations
2.7.1 Overview
2.7.2 Indication
2.7.3 Movement
2.7.4 Interval
2.7.5 Phase
2.7.6 Terminating a phase
2.8 Summary

Chapter 3 - Traffic Operations And Control at An Intersection
3.1 Introduction
3.2 Observer narrative and field data – traffic flow and controller operation
3.3 Models of what we've observed – vehicle flow
3.4 Models of what we've observed – controller operations
3.5 A model of state transition
3.6 State transition and the network precedence model

Chapter 4 – Detection and Timing Parameters
4.1 Introduction
4.2 Detection technology
4.3 Gap time
4.5 Example #1. Importance of detector location and minimum green time
4.6 Example 2. Presence vs. passage detection
4.7 Example 3. Long vs. short loops
4.8 Example 4 (zero passage time and zero minimum green time)
4.9 Summary and conclusions

Chapter 5 – vehicle clearance period
5.1 Introduction
5.2 Kinematics of safe stopping and intersection clearance.
5.3 Examples of stopping distance and intersection clearance
5.4 Effect of longer vehicles on clearance period
5.5 Statistical variability of speed, perception/reaction time, and deceleration rates
5.5.1 Variability in approach speed
5.5.2 Variability in perception/reaction times
5.5.3 Variability in deceleration rates
5.6 Setting of yellow and all red times based on vehicle change interval

5. Concluding Thoughts

This section presents a summary and conclusions from this study. The section also describes a new study recently funded by the Federal Highway Administration that will develop a set of laboratory exercises designed to educate practicing engineers and engineering students on traffic signal timing.

5.1 Summary and conclusions

This report presents the results from the project conducted to develop education materials for traffic signal operations. Materials have been developed for (1) providing needed information on signal timing and controller operations and (2) materials for case studies that are based on these preliminary materials.

The materials are in draft form and will be tested during the spring semester 2005. It is expected that revisions will be made as a result of this test. It is the intention of the author to continue to revise and test these materials as opportunities present themselves.

5.2 New study

Partly as a result of this work, the Federal Highway Administration has funded a new study whose objective is to develop a set of laboratory exercises. The project, known as MOST or mobile (hands-on) signal timing training, will provide skills and competencies needed by transportation engineers, technicians, and university students to use traffic data, existing traffic signal equipment, software programs, and resource material to determine and establish signal phasing and timing of individual installations of all types and systems of multiple signal installations for effective, efficient, and safe traffic control. The objective of this project is to develop, implement, and test a portable training course for traffic signal timing, including equipment, training materials, and educated instructors. Table 7 lists the laboratory exercises that will be developed. The project will be completed in 2007.

Table 7 Laboratory Exercises, MOST Project

Laboratory	Description
1	Demonstrate an example of the problems being addressed and the MOST traffic signal simulation and control environment
2	Understand impact of detector and timing parameters designed for cross street at isolated intersection
3	Understand impact of detector and timing parameters designed for arterial street at isolated intersection
4	Understand signal timing issues at an isolated intersection
5	Understand signal timing issues for isolated intersection with high volumes and heavy directional movements
6	Understand offsets (and related parameters) for well-spaced two intersection system
7	Understand offsets (and related issues) for irregularly-spaced oversaturated intersection system