ACTIVITY DEVELOPMENT FOR INTERSECTION OPERATIONS

The National Transportation Curriculum Project: Developing Activity-Based Learning Modules for the Introductory Transportation Engineering Course

Final Report

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16. Abstract

The goal of this work was to develop activity-based learning materials for the introductory transportation engineering course with the purpose of increasing student understanding and concept retention. These materials were to cover intersection operations from a multimodal transportation approach. The initial framework was to create a set of 4 activities, the first activity focused solely on automobile transportation, and the subsequent activities adding one additional transportation mode each. For the final work, the existing sequence of material in the textbook was used for activity development. The final work included the development of a handout for Dr. Kyte's critical movement analysis method, a queuing systems field lab, a pedestrian and bicycle level of service lab, and a transit level of service lab. The lab activities provided an active learning experience, two focusing on non-auto modes. These activities facilitated a fundamental and broad understanding of core concepts in transportation engineering. This work has provided me with a better perspective on instruction of this topic and with specific future goals, including better integration of multimodal transportation into the existing curriculum, addressing issues in the textbook, and fine-tuning the work that was previously completed.

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1.0 Overview

In the field of transportation engineering, it is becoming more important for engineers to understand the impact their work has on society as a whole. There is a new design paradigm in the industry focusing on sustainable and livable communities. This means that transportation engineers must consider the impact their work has on various transportation modes, such as walking, cycling, and transit modes rather than only on the automobile. Because of this shift, which emphasizes the importance of multimodal transportation, civil engineering students should be provided with an education that exposes them to multimodal transportation concepts. The introductory transportation engineering course, CE 372, at the University of Idaho, is a key time to expose students to these concepts. However, current textbooks lack the multimodal transportation perspective and there is a general lack of curriculum and teaching materials that incorporate this important idea.

There is also a lack of activity-based learning materials for the introductory transportation engineering course. Transportation engineering instructors across the country want to promote student-centered learning rather than instructor-centered learning, which focuses on greater understanding and retention of core concepts.

2.0 Scope

The scope of my work was to develop activity-based learning materials for CE 372. Activity-based learning attempts to provide an active learning environment where students are solving problems and participating in their own learning process. These materials were intended to cover intersection operations from a multimodal transportation approach and to fit into a 3 to 4 week period. The initial goal was to start with an activity at a specific intersection and with a single class of users (automobiles) and to develop three additional activities at new intersections, adding other classes of users in sequence.

A secondary goal was to develop other learning materials, such as a library of photographs and videos that show aspects of multimodal transportation. Such a library could aid in teaching the topic of multimodal traffic operations.

3.0 Multimodal Curriculum for Intersections

There are several issues involved with teaching multimodal transportation in the introductory transportation engineering course. These issues include the current lack of curriculum, the challenge of providing a "bigger picture" learning experience rather than a "get lost in the details" experience, and the difficulty of integrating this material into the existing curriculum structure.

There is a current lack of the multimodal transportation perspective in the introductory transportation engineering class. As it is becoming more important for transportation engineers to evaluate the effect their work has on society as a whole, engineering curriculum should incorporate pedestrian, bicycle, and transit users. Unfortunately, the automobile user is nearly the sole focus in existing transportation curriculum, which means that instructors have a lack of guidance in preparing students for this new design paradigm. For this reason, students are not receiving adequate training at the university level in considering multimodal transportation concerns.

Another barrier to the instruction of multimodal concepts is that it is difficult to create activities that introduce the topic of transportation engineering in a bigger picture sense without losing students in the details. What is the appropriate difficulty and detail level for the introductory course? The goal in developing the curriculum is to expose students to multimodal concepts with technically challenging activities that provide them with deeper learning. Activities that are too detail-oriented tend to lose students in particulars and not teach the important overall core concepts. Because of the lack of learning materials, the resources available for instructors are comprised of the resources used by professionals. These resources, though thorough, are often too technical or too detailed for immediate use for junior level students. If these resources are used, guidance or simplification of the material is needed.

The final issue is the difficulty posed in integrating multimodal activities into the current curriculum structure. Developing activities that perfectly integrate with the order in which textbooks are written presents a challenge. The multimodal activities that were originally developed were intended to address core competencies at the same time as multimodal transportation but, in order to flow well, sometimes required a different sequence of instruction than that in the course textbook.

4.0 Initial Work

The initial framework for this project was to create a set of four activities, each located at different intersections. The first activity would be automobile-based and each consecutive activity would add an additional transportation mode—pedestrians, bicycles, and finally transit. From this framework I developed a set of problem statements for each intersection. I then developed two activities, one for the automobile-focused problem, and one for the automobile and pedestrian-focused problem. Because of time constraints and structural issues, these activities were not used in class, but they could provide future uses.

4.1 Problem 1

Problem 1 was automobile-focused and was set at the intersection of Palouse River Drive and Highway 95 in Moscow. The learning objective was for students to understand and apply phasing and critical movement analysis to the intersection to gain an understanding of intersection capacity and delay. The final draft is shown in Appendix A. It involved students making math-based decisions about protected vs. permitted left turns, completing a critical movement analysis using the textbook method, calculating the appropriate cycle length, and evaluating the intersection level of service (LOS) performance based on current and future traffic volumes. LOS is a national letter-based system used to evaluate the performance of transportation facilities. Problem 1 attempted to prompt deeper understanding of the relationships between various traffic volume and signal control characteristics.

4.2 Problem 2

Problem 2 added the next sequential user mode, the pedestrian. Set at Peterson Drive and State Highway 8, the learning objective of this activity was to facilitate understanding of intersection capacity and delay from the perspective of two users, the automobile and the pedestrian. I also wanted students to be exposed to the reality of balancing user priorities and user needs. Similar to problem 1, it required a critical movement analysis, cycle length calculations, and a LOS-based intersection evaluation. However, it also included a pedestrian LOS analysis. The final draft of this activity is included in Appendix B.

4.3 Outcomes

Although these activities were not used in the classroom, the process provided benefits. For problem 2, a pedestrian LOS method was developed. This consisted of a summary and simplification of the Highway Capacity Manual (HCM) method which was used as a base for one of the final activities I developed. This process also provided me with some interesting insights. When developing activities it is easy to get lost in the details and stray from the "student centered" learning that is so important. The goal is to teach students main ideas, and extremely lengthy activities with extraneous calculations do not support this goal. Secondly, I learned how challenging it is to incorporate multimodal transportation topics into a previously created curriculum structure. Certain concepts that were needed for my first activity were in sections of the book that were not covered yet. When developing activities, it is important to be aware of what students have learned and the appropriate sequence of activities.

5.0 Final Work

The work that was used in the classroom followed the existing sequence of material in the textbook. The traditional material was supplemented with activity-based learning activities and two activities focused entirely on non-automobile transportation modes. The goal of the final work was to get students as involved and engaged as possible, facilitating long-term understanding and learning retention. For the traffic operations section of the class, four activities were developed and used in the class, including a critical movement analysis comparison (assignment 24), field observation of delay (lab 9), pedestrian and bicycle LOS at an intersection (lab 11), and transit LOS (lab 12).

5.1 Critical Movement Analysis Comparison (assignment 24)

One important concept in the introductory transportation engineering course is the critical movement analysis. The textbook method of this process is different than that taught by others. The purpose of this in-class assignment was to provide students with a conceptual understanding of the differences in the two methods. My work for this assignment consisted of creating the critical movement analysis handout that details the process used by Dr. Michael Kyte. This handout is provided in Appendix C.

5.2 Queuing Systems: Field Observations (lab 9)

In this activity, included in Appendix D, students were asked to observe queuing in the field. The learning objective was to be able to describe the queuing behavior and to be able to compare the D/D/1 queuing model with traffic behavior in the field. Students recorded the time cars entered and exited the intersection system for one approach at an intersection using a provided data collection sheet. Based on their field data, they prepared queuing diagrams and queue accumulation polygons. They also calculated delay and estimated intersection approach performance.

5.3 Pedestrian and Bicycle LOS at an Intersection (lab 11)

This lab activity, included in Appendix E, was completely focused on multimodal transportation, specifically pedestrians and bicycles. The purpose was for students to estimate the pedestrian and bicycle LOS for an intersection based on intersection geometry and demand characteristics. Students were asked to collect geometric data and traffic volume data from the field using a provided data collection form. The students then estimated the performance of the intersection using a summary table and the HCM equations, which were simplified and made more user-friendly. Additionally, they were asked to think about how the specific geometric and demand characteristics affected LOS and which ones had the largest effects.

5.4 Transit LOS (lab 12)

The last activity I developed was concerned with estimating the transit comfort and convenience LOS in Moscow. Shown in Appendix F, this activity was meant to provide students with insight into how bus service characteristics affect quality of experience and the public decision to ride the bus. Students were assigned departure and destination locations around Moscow and rode the bus to determine the door-to-door travel time associated with the trips. They then compared this travel time to the estimated automobile travel time and calculated the travel time difference, which is a LOS measure.

6.0 Future Work

The work I have completed over the past several months has provided me with a good starting point for future work. The next phase of my work should include the following: increasing the presence of multimodal transportation in the introductory transportation engineering curriculum, addressing issues in the current version of the textbook, addressing ways to clarify concepts, and further developing the activities that I have completed.

Although I have developed several activities, I think this topic warrants further growth. It may be possible to further incorporate multimodal transportation into the curriculum. It may also be possible to sequentially address learning materials in the book with the multimodal transportation perspective. An original idea for this project was to create a problem that encompasses all four transportation modes, and this has not yet been done.

There are two serious issues with the current version of the textbook. The first issue is that the term “phase” is used inconsistently. In some locations the text refers to the “8 phase controller” while in others it refers to 2 and 3 phase controller operations. My next steps could include identifying ways in which the term is used inconsistently and also trying to find a way to more accurately describe the topics that are being discussed. Another issue is that the critical movement analysis method used in the text is not consistent with the method taught by others. It may be worth developing a text-worthy version of the critical movement analysis method used by Dr. Kyte for students to use.

My upcoming work should include thought on how to clarify concepts for students. I will have access to student exams which will provide me with insight into common misconceptions in traffic engineering. Based on these exams I should be able to identify ways to clarify concepts for students so that they learn better with less confusion.

Similarly, I need to further develop the activities that I have already completed. There were some misunderstandings about the labs, specifically lab 11 on the pedestrian and bicycle LOS. For example, one variable was mislabeled and although it was corrected by the instructor it seemed to cause a high level of confusion. Also, the equations that I simplified from the HCM may be too compact. I think breaking up the equations into smaller pieces may better facilitate understanding about how various geometric and demand characteristics affect pedestrian and bicycle comfort and safety. Another issue I identified while looking through a few of the completed labs is that students did not always complete all of the steps in the labs. Students may have missed a step due to lack of clarity. Adding clarity to labs 9 and 10 specifically should reduce the chance of students not completing all steps.

7.0 Conclusion

Several activity-based learning materials were developed for the introductory transportation engineering course. The activities provided a real-world learning experience to students, in the hope of better facilitating a fundamental and broad understanding of core concepts in traffic engineering. Two of the activities focused on multimodal transportation issues, which, as discussed above, are becoming increasingly important for transportation engineers to understand and to design for. The work completed over the past several months has provided me with insight into the difficulties of curriculum development. My understanding of “big picture” curriculum development and the difficulties of curriculum integration has provided me with a better starting perspective in instruction of this topic. Also, based on the work I have completed, I now have specific goals for my future work, which include better integrating multimodal transportation into the existing curriculum, addressing issues in the textbook, and fine-tuning work that I have previously done. Over the next several months, more progress will be made towards these goals.

Appendix A: Automobile Problem

Palouse River Drive and Highway 95

A new development on the east side of Moscow is changing the characteristics of traffic demand at the intersection of Palouse River Drive and Highway 95. There is also more proposed development on east Palouse River Drive and west Palouse River Drive. Design a signal timing plan based on the current traffic volumes at this intersection. Based on the future estimated traffic demand, how will your timing plan perform?

Part 1: Design a signal timing plan based on the current traffic volumes. Evaluate performance of signal timing plan.

Activity 1

Learning objectives: Understand and apply phasing and critical movement analysis to intersection to gain understanding of intersection capacity and delay.

In class introduction on Friday: Go over problem statement and learning objectives. Introduction to signal control and phasing. Start Activity 1a.

Activity 1a (homework) Over weekend

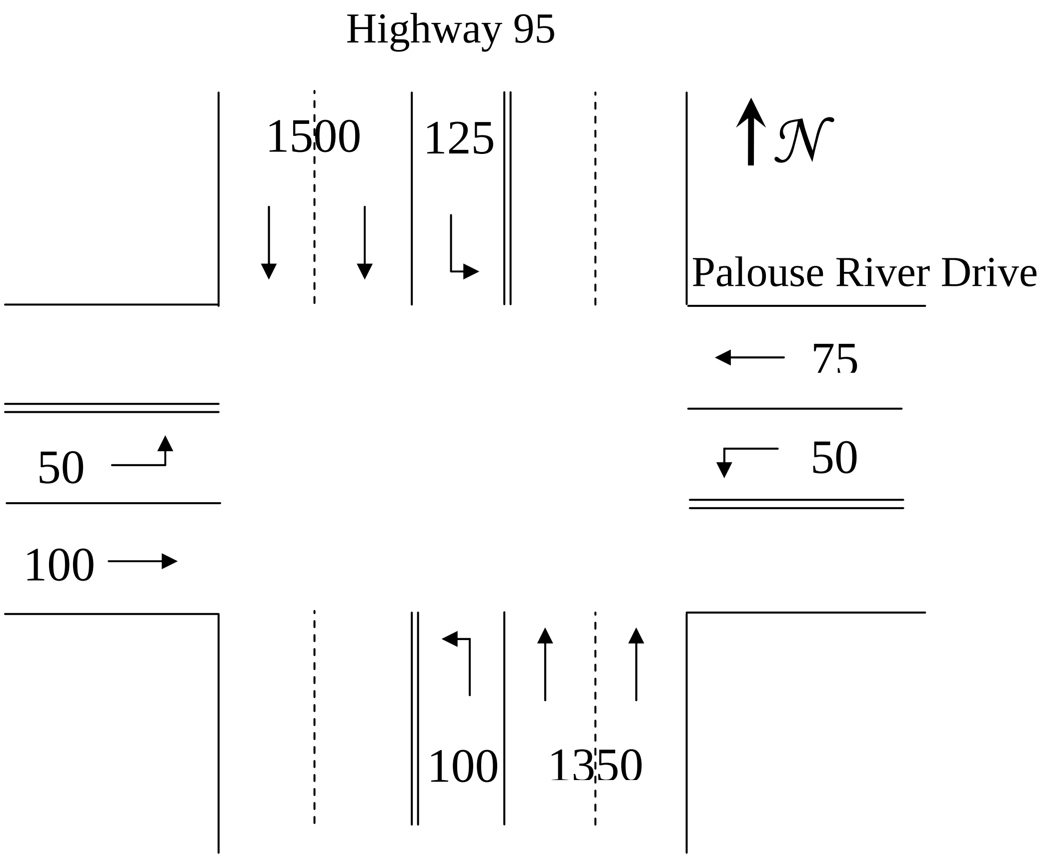
Read 7.2 Intersection and Signal control characteristics. 7.5.1, 7.5.2, 7.5.4, 7.5.5.

For the Palouse River Drive and Highway 95 intersection, complete phasing.

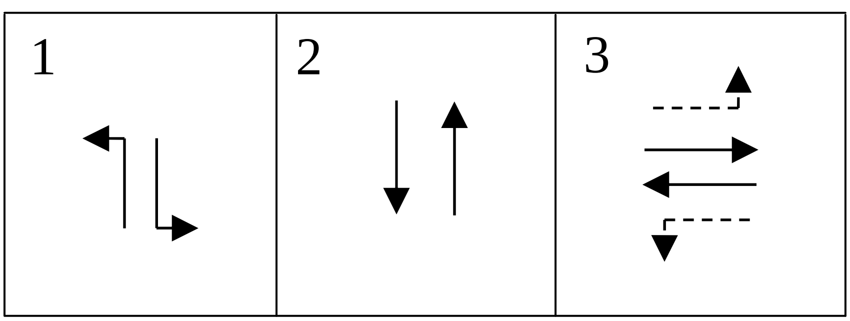
Phasing:

1. Identify movements.
2. Determine if left turn phases should be provided using the cross-product guideline.

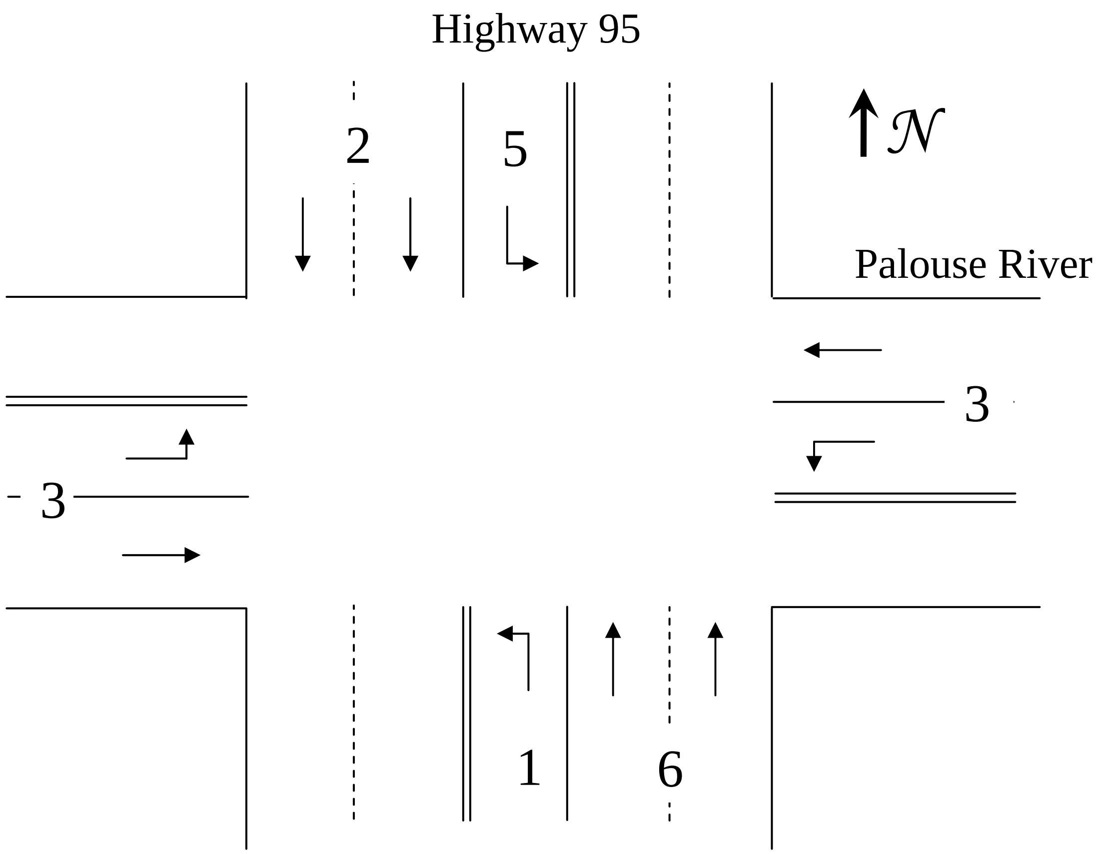
Movements	Cross product	Opposing Lanes	Protected left turns required?
WBTH and EBLT	3750	1	No
EBTH and WBLT	5000	1	No
NBTH and SBLT	168750	2	Yes
SBTH and NBLT	150000	2	Yes



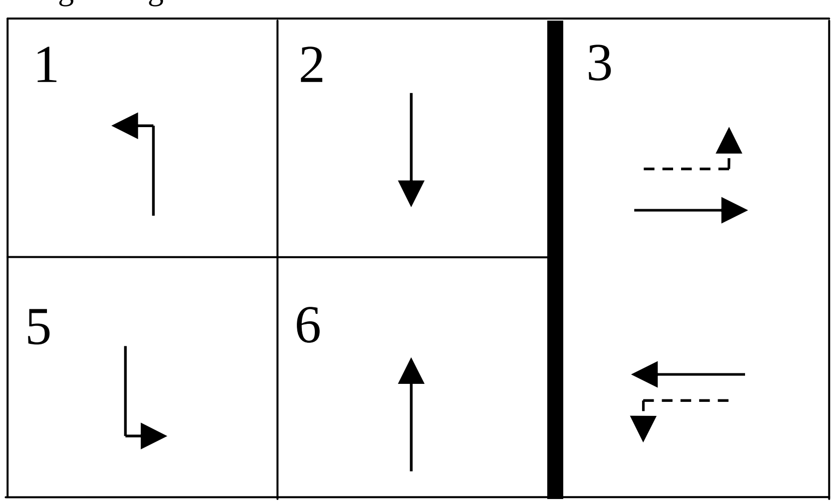
3. Assign phases.



4. Assign phases to intersection.



7. However, protected phasing can be independent. Arrange independent movements into the dual-ring configuration.



Activity 1b (Monday in class)

Do steps in 7.5.4, 7.5.5

1. Determine critical lane groups and the sum of the flow ratios. Assume non-overlapping phases. Calculate the minimum and optimal cycle length.

Saturation Flow Rates* for Three-Phase design (veh/hr)

Phase 1		Phase 2		Phase 3	
NBLT	1750	NBTH	3400	WBLT	475
SBLT	1750	SBTH	3400	EBLT	475
				WBTH	1800
				EBTH	1800

*Provided to students

Flow Ratios and Critical Lane Groups

Phase 1		Phase 2		Phase 3	
NBLT	0.057	NBTH	0.397	WBLT	0.105
SBLT	0.071	SBTH	0.441	EBLT	0.105
				WBTH	0.042
				EBTH	0.056

(Critical lane groups indicated by highlighting)

$$Y_c = \sum_{i=1}^{n} (\frac{v}{s})_{ci}$$

Sum = Y_c = 0.618

2. Calculate cycle length. Assume lost time = 4s per critical lane group and X_c = .85.

$$C_{min} = \frac{L \times X_c}{X_c - \sum_{i=1}^{n} (\frac{v}{s})_{ci}}$$

C_{min} = 43.9s or 45s*

*Round up to nearest 5s increment.

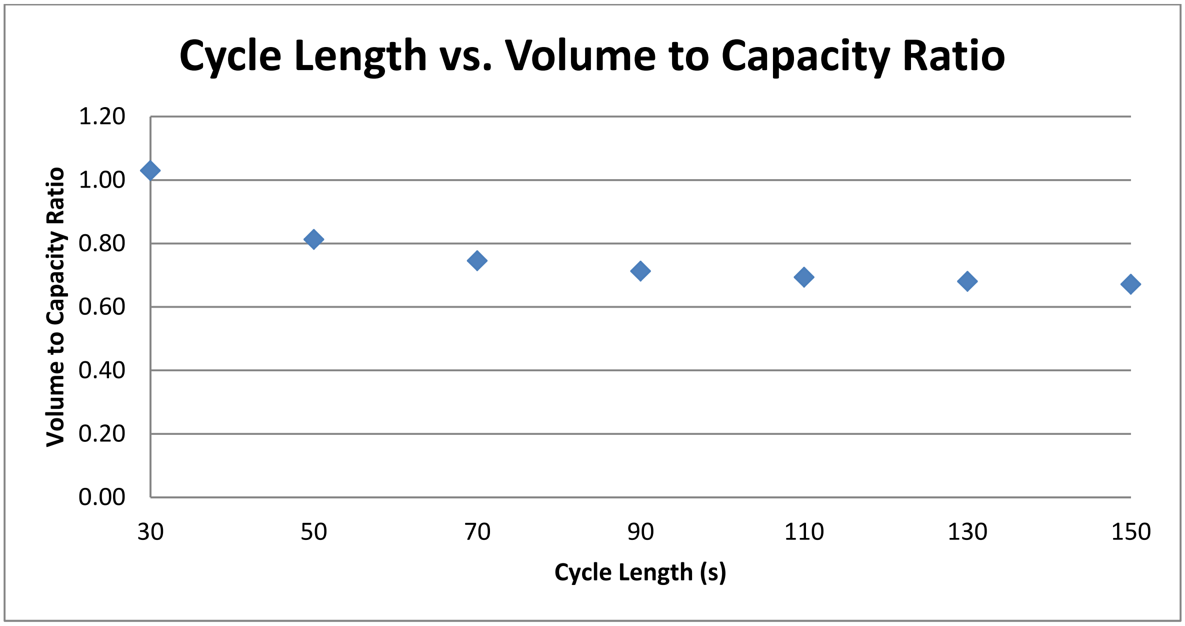
$$C_{opt} = \frac{1.5 \times L + 5}{1 - \sum_{i=1}^{n} (\frac{v}{s})_{ci}}$$

C_{opt}= 60.2 or 60s.

Activity 1c (Monday night)

Read 7.3.3 Signalized Intersection Analysis of Level of Service

1. Calculate critical volume to capacity ratio for several cycle lengths for this intersection. Assume a lost time of 4s per phase. Display in graph form. Hint: use eq. 7.20.

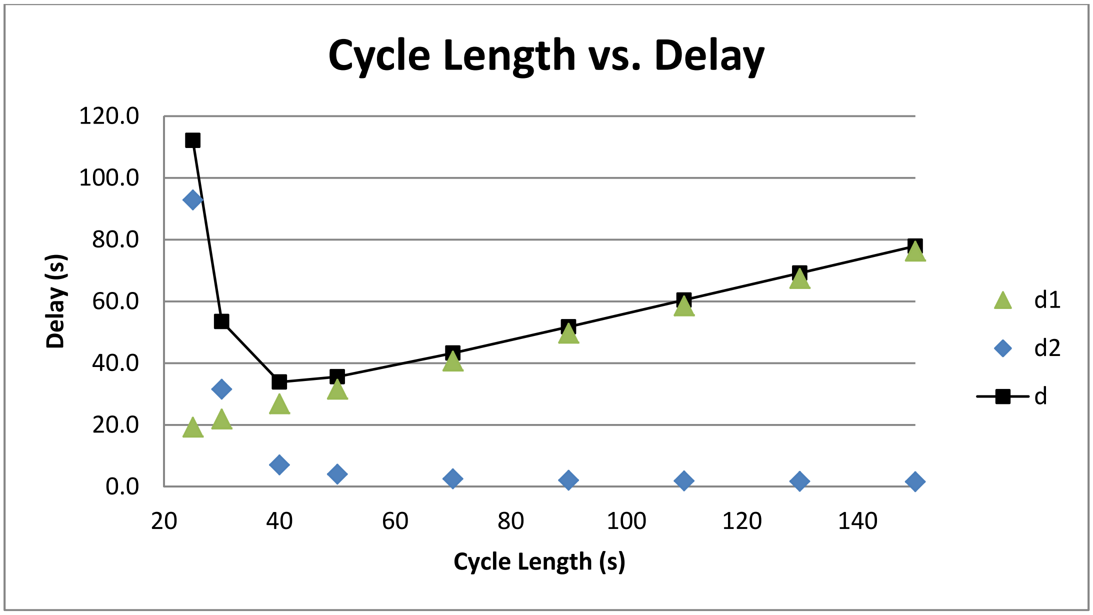


2. Calculate and display average delay per vehicle due to uniform arrivals and due to random arrivals for several cycle lengths for one approach. Also calculate and show average signal delay per vehicle, assuming delay due to the initial queue is negligible. I used phase2, SBTH approach.

$$d_1 = \frac{0.5 \times C\left(1 - \frac{g}{C}\right)^2}{1 - \left[\min(1, X)\frac{g}{C}\right]}$$

$$d_2 = 900T\left[(X - 1) + \sqrt{(X - 1)^2 + \frac{8kIX}{cT}}\right]$$

$$d = d_1 \times PF + d_2 + d_3$$



3. Examine the relationships between cycle length, volume to capacity ratio, and delay.

Read 7.5.6

Activity 2 (Wednesday in class)

Learning objectives: Understand signal timing parameters. Analyze a signal control plan and evaluate performance of the intersection.

Review homework. Estimate signal timing parameters for current traffic volumes.

1. Allocate green time. Use the minimum cycle length.

$$g_i = \left(\frac{v}{s}\right)_{ci} \left(\frac{C}{X_i}\right)$$

Based on example 7.11, Xi=0.84.

Effective green times for minimum cycle length

Phase	Time (s)
NBLT and SBLT	3.8
NBTH and SBTH	23.6
EBTH,WBTH,EBLT,WBLT	5.6

Check: 3.8+23.6+5.6+12 = 45 good

How do you think changes in cycle length will affect traffic?

2. Allocate green time using the optimal cycle length.

Optimal Green times

Phase	Time (s)
NBLT and SBLT	5.5
NBTH and SBTH	34.3
EBTH,WBTH,EBLT,WBLT	8.2

3. Estimate and evaluate performance of the intersection for current traffic volumes for the minimum cycle length and the optimal cycle length.
   a. Calculate uniform delay, random delay, and total signal for each critical approach. As before, assume start-up delay is negligible.

Minimum Cycle Length

Critical Movement	Phase	Green (s)	X	Uniform Delay (s)	Random Delay (s)	Total Delay (s)
SBLT	1	3.8	0.84	20.3	40.6	60.9
SBTH	2	23.6	0.84	9.1	5.0	14.0
EBTH	3	5.6	0.44	18.2	6.2	24.4
WBLT	3	5.6	0.84	19.2	76.8	96.1
			Sum =	66.8	128.6	195.4

Optimal Cycle Length

Critical Movement	Phase	Green (s)	X	Uniform Delay (s)	Random Delay (s)	Total Delay (s)
SBLT	1	5.5	0.77	26.6	29.3	55.9
SBTH	2	34.3	0.77	9.9	3.1	12.9
EBTH	3	8.2	0.41	23.7	5.0	28.7
WBLT	3	8.2	0.77	25.0	59.6	84.6
			Sum =	85.2	97.0	182.2

4. Estimate LOS for each approach based on the total delay. Is the 45s cycle length the most appropriate? What changes could improve operation of the intersection?

Minimum Cycle Length

Critical Movement	Phase	Total Delay (s)	LOS
SBLT	1	62.0	E
SBTH	2	14.0	B
EBTH	3	24.4	C
WBLT	3	96.1	F

Optimal Cycle Length

Critical Movement	Phase	Total Delay (s)	LOS
SBLT	1	55.9	E
SBTH	2	12.9	B
EBTH	3	28.7	C
WBLT	3	84.6	F

Which cycle length is more appropriate?

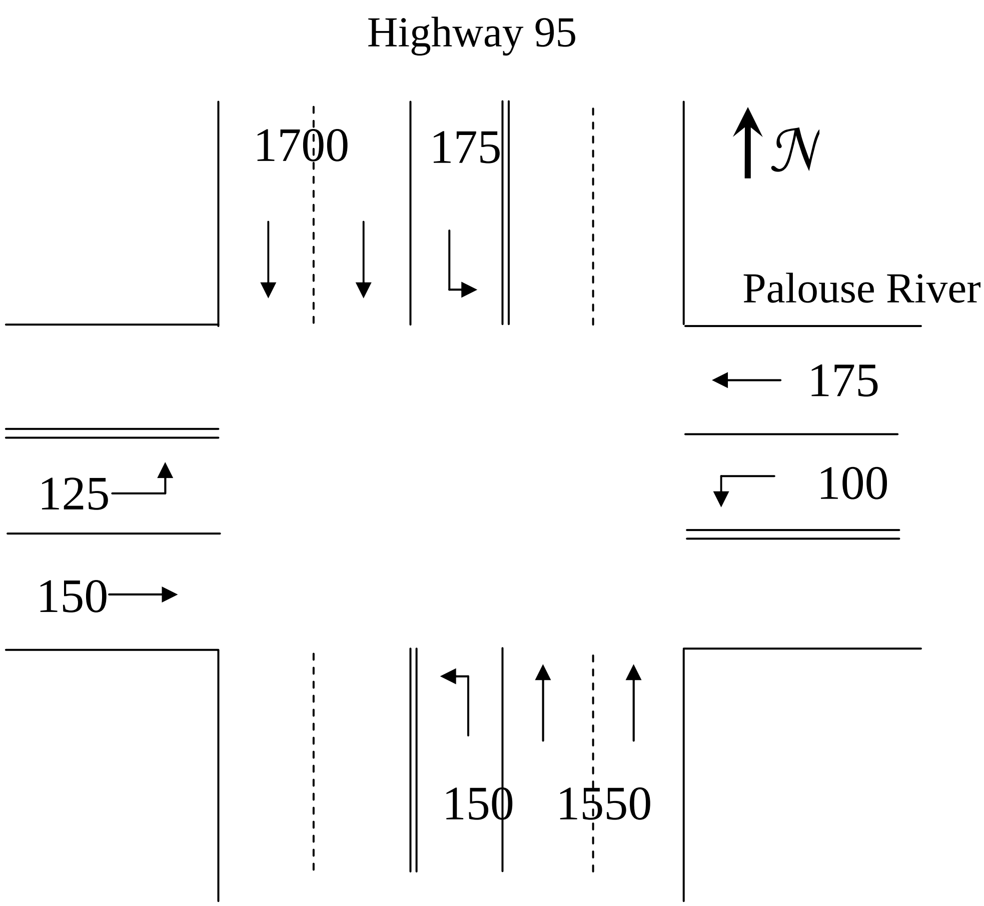
Part 2: Based on the future estimated traffic demand, how will your timing plan perform?

Activity 3

Learning objectives: Evaluate signal timing plan for increased traffic volumes and analyze signal timing parameters.

Activity 3a (Wednesday night homework)

1. Determine critical lane groups and the sum of the flow ratios. Assume non-overlapping phases.



Movements	Cross product	Opposing Lanes	Protected left turns required?
WBTH and EBLT	12500	1	No
EBTH and WBLT	15000	1	No
NBTH and SBLT	271250	2	Yes
SBTH and NBLT	255000	2	Yes

Flow Ratios and Critical Lane Groups

Phase 1		Phase 2		Phase 3	
NBLT	0.086	NBTH	0.456	WBLT	0.211
SBLT	0.100	SBTH	0.500	EBLT	0.263
				WBTH	0.056
				EBTH	0.083

Yc = .863

2. Evaluate signal timing plan for future demand. (Used optimal cycle length)

Critical Movement	Phase	Green (s)	X	Uniform Delay (s)	Random Delay (s)	Total Delay (s)
SBLT	1	5.5	1.08	27.5	94.1	121.5
SBTH	2	34.3	0.88	11.0	5.9	16.9
EBTH	3	8.2	0.61	24.4	10.9	35.3
EBLT	3	8.2	1.93	30.4	470.3	500.6
			Sum =	93.3	581.1	674.4

Critical Movement	Phase	Total Delay (s)	LOS
SBLT	1	121.5	F
SBTH	2	16.9	B
EBTH	3	35.3	D
EBLT	3	500.6	F

Is this an acceptable level of delay?

Activity 3b (in class)

Learning objectives: Evaluate signal timing plan based on visualization of plan.

1. Put signal timing plan and original traffic volumes into VISSIM. Observe.
    a. Compare performance of VISSIM network to calculated performance measures.
    b. What do you observe in the simulation?
    c. Is the expected performance based on the calculated uniform delay reflected in the simulation?
    d. For the NBLT, WBLT, and EBTH approaches do you observe some cycle failure?
2. Put new volumes into old VISSIM setup.
    a. What do you expect to observe? What do you observe? Do you think the intersection is operating efficiently? What changes can be made to the signal control plan to improve the operation?
    b. Compare performance of intersection for new and old volumes.
    c. Compare calculated and observed performance measures.

Part 3: Compare the plans and the performance of the two plans.

Activity 4 (Thursday night homework questions and discussion in class Friday)

Learning objectives: Evaluate signal timing plans and understand planning implications of development.

Complete before class and discuss together in class.

1. Compare signal timing plans.
2. How does the old signal timing plan perform for the new traffic volumes?
3. Compare the performance of the old signal timing plan and the new signal timing plan for the new volumes.
4. How does development in this area affect the performance of the intersection? What changes to the signal timing plan were necessary to meet the needs of the new traffic demand characteristics?

Appendix B: Auto and Pedestrian Problem

Peterson Drive and State Highway 8

The intersection at State Highway 8 and Peterson Drive in Moscow has a high volume of automobile traffic and a high volume of pedestrian traffic. For this reason, it was recently changed from a three-legged stop controlled intersection, with a north-south crosswalk, to a four-legged signal controlled intersection. Design a signal timing plan for the signal-controlled intersection based on the automobile traffic volumes. How does it perform for vehicles? Now analyze how the automobile-centered design performs for pedestrians. How does the timing plan/control need to be changed to better suit the needs of pedestrians? Design a signal timing plan that most appropriately meets the needs of both automobile and pedestrian traffic.

Part 1: Design a signal timing plan based on automobile traffic volumes. Evaluate performance of a signal timing plan for automobiles. Evaluate performance of a signal timing plan for pedestrians.

Activity 1

Learning objectives: Understand and apply phasing and critical movement analysis to intersection to gain understanding of intersection capacity and delay.

In-class introduction - Friday half class: Go over problem statement and learning objectives. Introduction to signal control and phasing. Start homework problem.

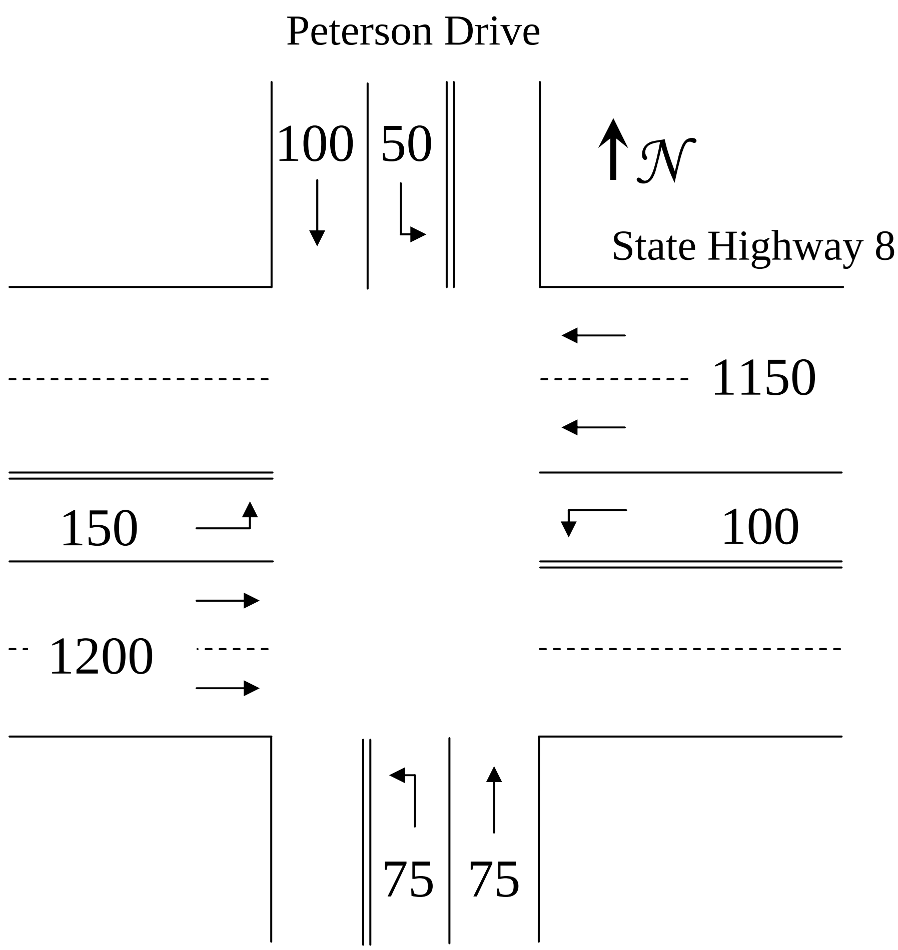
Activity 1a (weekend homework)

Read 7.2 intersection and signal control characteristics, 7.5.1 and 7.5.2, signal phasing and lane groups.

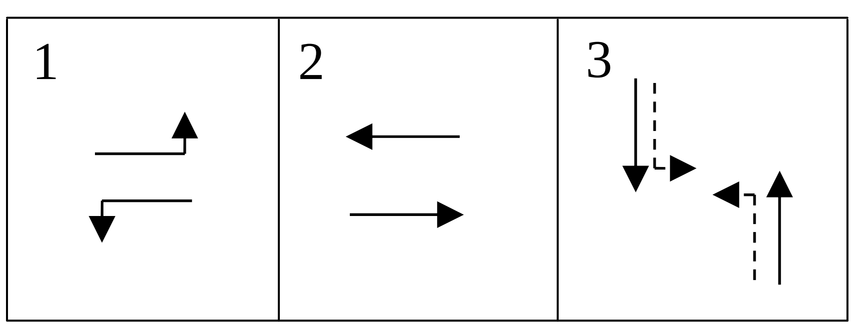
For the Palouse River Drive and Highway 95 intersection, complete phasing.

1. Identify movements.
2. Determine if left turn phases should be provided using the cross-product guideline.

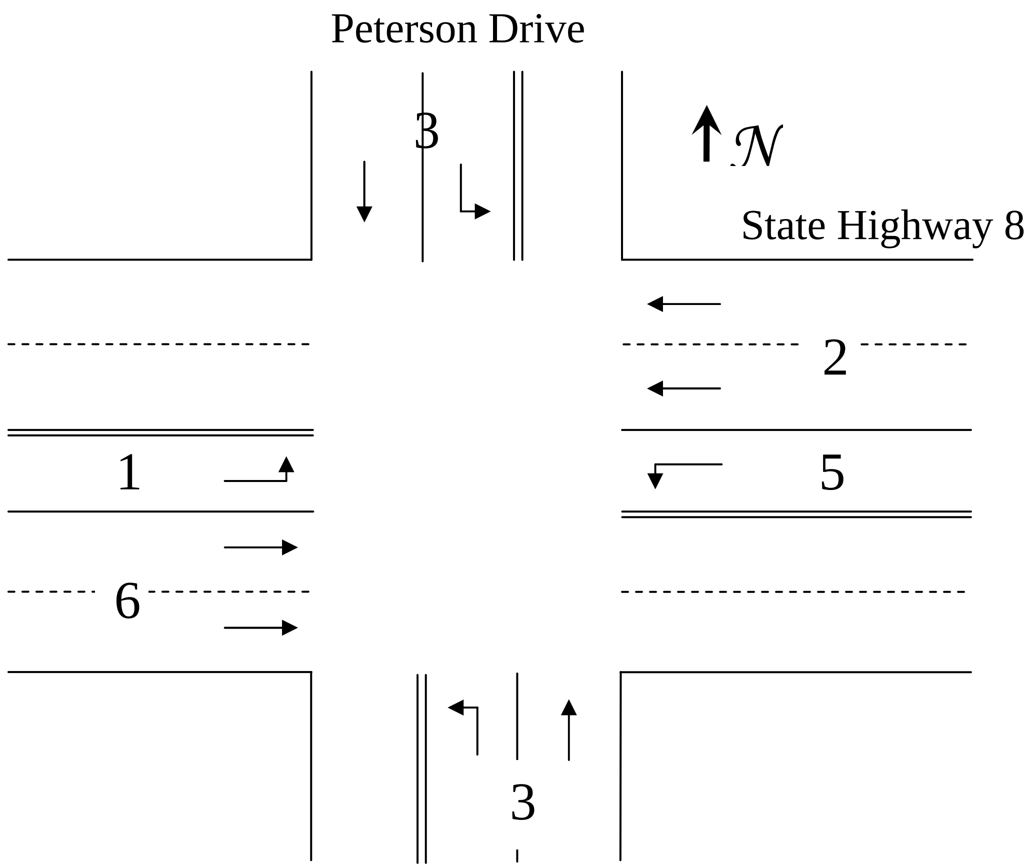
Movements	Cross product	Opposing Lanes	Protected left turns required?
WBTH and EBLT	172500	2	Yes
EBTH and WBLT	120000	2	Yes
NBTH and SBLT	3750	1	No
SBTH and NBLT	7500	1	No



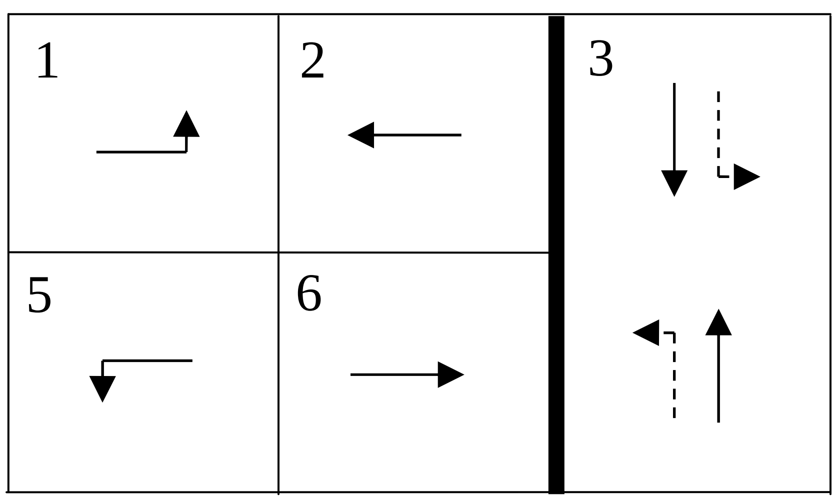
3. Assign phases.



4. Assign phases to intersection.



5. However, protected phasing can be independent. Arrange independent movements into the dual-ring configuration.



Activity 1b (Monday class)

Learning objectives: Understand and apply critical movement analysis to intersection to gain understanding of intersection capacity and delay.

Do steps in 7.5.4, 7.5.5

Critical Volumes per lane

Movement	EBLT	WBTH	WBLT	EBTH	NBLT	SBTH	SBLT	NBTH
Critical Volume	150	575	50	600	75	100	50	75

1. Determine critical lane groups and the sum of the flow ratios. Assume non-overlapping phases. Calculate the minimum and optimal cycle length.

Saturation Flow Rates* for Three-Phase design (veh/hr)

Phase 1		Phase 2		Phase 3	
WBLT	1750	WBTH	3400	NBLT	475
EBLT	1750	EBTH	3400	SBLT	475
				NBTH	1800
				SBTH	1800

*Provided to students

Flow Ratios and Critical Lane Groups

Phase 1		Phase 2		Phase 3	
WBLT	0.057	WBTH	0.338	NBLT	0.158
EBLT	0.086	EBTH	0.353	SBLT	0.105
				NBTH	0.042
				SBTH	0.056

$$Y_c = \sum_{i=1}^{n} \left(\frac{v}{s}\right)_{ci}$$

Sum = Y_c = 0.597

1. Calculate cycle length. Assume lost time=4s per critical lane group and X_c = .85.

$$C_{min} = \frac{L \times X_c}{X_c - \sum_{i=1}^{n}(\frac{v}{s})_{ci}}$$

C_{min} = 40.2s or 45s*

*Round up to nearest 5s increment.

$$C_{opt} = \frac{1.5 \times L + 5}{1 - \sum_{i=1}^{n}(\frac{v}{s})_{ci}}$$

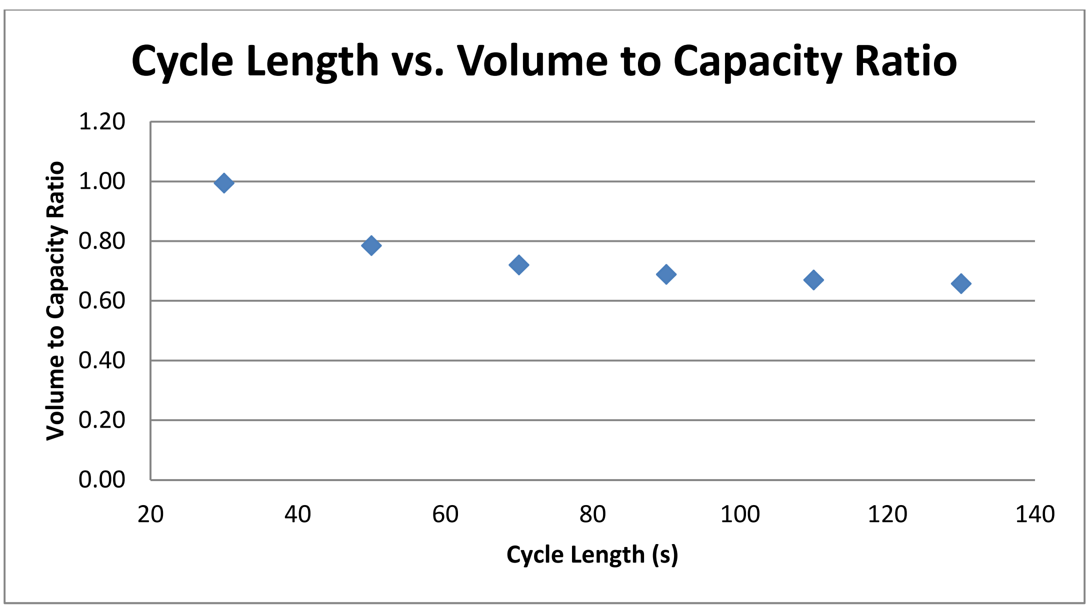
C_{opt}= 57.0 or 55s.

Activity 1c (Monday night homework)

Read 7.3.3 Signalized Intersection Analysis of Level of Service

Calculate capacity, uniform delay, and random delay for several cycle lengths. Examine the relationships. Calculate ideal cycle length for ideal Xcm.

1. Calculate critical volume to capacity ratio for several cycle lengths for this intersection. Assume a lost time of 4s per phase. Display in graph form. Hint: use eq. 7.20.



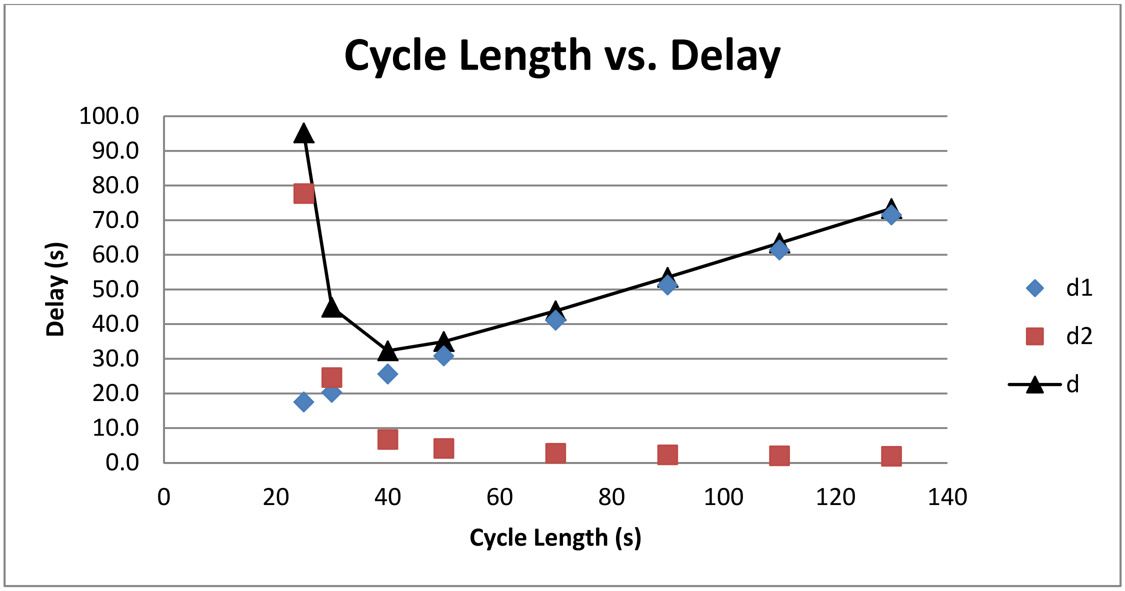
2. Calculate and display average delay per vehicle due to uniform arrivals and due to random arrivals for several cycle lengths for one approach. Also calculate and show

average signal delay per vehicle, assuming delay due to the initial queue is negligible. I used phase2, SBTH approach.

$$d_1 = \frac{0.5 \times C\left(1 - \frac{g}{C}\right)^2}{1 - \left[\min(1, X)\frac{g}{C}\right]}$$

$$d_2 = 900T\left[(X-1) + \sqrt{(X-1)^2 + \frac{8kIX}{cT}}\right]$$

$$d = d_1 \times PF + d_2 + d_3$$



3. Examine the relationships between cycle length, volume to capacity ratio, and delay.

Read 7.5.6

Activity 2 (Wednesday class)

Learning objectives: Understand signal timing parameters. Analyze a signal control plan and evaluate performance of the intersection.

Review homework. Estimate signal timing parameters for current traffic volumes.

4. Allocate green time. Use the minimum cycle length.

$$g_i = \left(\frac{v}{s}\right)_{ci}\left(\frac{C}{X_i}\right)$$

Based on example 7.11, Xi=0.81.

Minimum Effective Green times

Phase	Time (s)
WBLT, EBLT	4.7
WBTH, EBTH	19.5
NBLT, SBLT, NBTH, SBTH	8.7

Check: 4.7+19.5+8.7+12 = 45 good

How do you think changes in cycle length will affect traffic?

5. Allocate green time using the optimal cycle length.

Optimal Green times

Phase	Time (s)
WBLT, EBLT	6.2
WBTH, EBTH	25.4
NBLT, SBLT, NBTH, SBTH	11.4

6. Estimate and evaluate performance of the intersection for current traffic volumes for the minimum cycle length and the optimal cycle length.
   a. Calculate uniform delay, random delay, and total signal for each critical approach. As before, assume start-up delay is negligible.

Minimum Cycle Length

Critical Movement	Phase	Green (s)	X	Uniform Delay (s)	Random Delay (s)	Total Delay (s)
EBLT	1	4.7	0.81	19.7	31.1	50.8
EBTH	2	19.5	0.81	11.1	5.0	16.2
NBLT	3	8.7	0.81	17.4	52.4	69.8
SBTH	3	8.7	0.29	15.5	2.1	17.5
			Sum =	63.7	90.6	154.2

Optimal Cycle Length

Critical Movement	Phase	Green (s)	X	Uniform Delay (s)	Random Delay (s)	Total Delay (s)
EBLT	1	6.2	0.76	23.7	24.1	47.8
EBTH	2	25.4	0.76	12.3	3.6	15.8
NBLT	3	11.4	0.76	20.5	42.2	62.8
SBTH	3	11.4	0.27	18.3	1.8	20.1
			Sum =	74.8	71.6	146.5

7. Estimate LOS for each approach based on the total delay. Is the 45s cycle length the most appropriate? What changes could improve operation of the intersection?

Minimum Cycle Length

Critical Movement	Phase	Total Delay (s)	LOS
EBLT	1	50.8	D
EBTH	2	16.2	B
NBLT	3	69.8	E
SBTH	3	17.5	B

Optimal Cycle Length

Critical Movement	Phase	Total Delay (s)	LOS
EBLT	1	47.8	D
EBTH	2	15.8	B
NBLT	3	62.8	E
SBTH	3	20.1	C

Which cycle length is more appropriate?

Activity 2c (Wednesday night homework)

Evaluate performance of the intersection with regard to pedestrians. Focus on N-S crosswalk crossing Moscow/Pullman highway.

1. Calculate pedestrian delay (HCM), minimum crossing time (text), and LOS score using Maria's methodology (HCM).

Minimum pedestrian green time (s):

$$G_p = 3.2 + \frac{L}{S_p} + (0.27N_p)$$

Critical Movement	Phase	Volume (vphpl)	Green (s)	Crosswalk Length(ft)	Minimum Crossing Time (s)	Pedestrian Delay (s)	Pedestrian LOS
WBTH	2	575	19.5	40	14	7	
SBTH	3	100	8.7	68	21	15	C

a. Is it safe for pedestrians to cross the street with this signal timing plan?
b. Check delay. Is delay less than 30s/pedestrian? If not, pedestrians tend to ignore signal control. (as per HCM 18-69)

Part 2: Design a signal timing plan that most appropriately meets the needs of pedestrian traffic. Evaluate performance of new plan for automobile and pedestrian needs.

Activity 3

Learning objectives: Understand signal timing parameters. Analyze a signal control plan and evaluate performance of the intersection. Analyze conflicts between users.

Activity 3a (Thursday)

Design signal timing plan with respect to pedestrians.

1. Calculate minimum pedestrian crossing time for both crosswalks.
2. Adjust through green times to coincide with pedestrian crossing times.

Activity 3b

Estimate performance of new plan for pedestrians and automobiles.

3. Estimate and evaluate performance of new plan for pedestrians.
4. Estimate and evaluate performance of new plan for automobiles.

Part 3: Compare the plans and the performance of the two plans.

Activity 4

Learning objectives: Analyze conflicts between users and evaluate performance of an intersection from a multimodal perspective.

Thursday homework: Answer the following questions and discuss answers in class on Friday.

1. Compare the plans and the performance of the plans. How did the original signal timing plan perform for pedestrians vs the new signal timing plan? How did the performance of the intersection with regard to autos change?
2. What changes were needed to accommodate pedestrians? How did accommodating pedestrians affect automobiles?
3. Would you use either signal timing plan as a final signal timing plan? Would you alter a plan for the final design?
4. Which users should receive priority at this intersection? At a different intersection, say Palouse River Drive and Highway 95? Downtown or university intersections? Does land use have anything to do with which users should receive priority? Does transportation engineering design affect user demand or does it respond to user demand?

5. What other changes could be made to the intersection, besides traffic control, to make it more pedestrian friendly (hint: think about the physical characteristics of the intersection and factors affecting the design).

Appendix C: Critical Movement Analysis Handout

The purpose of the CMA is to identify the critical movements at an intersection and to identify whether there is sufficient capacity to serve the estimated volumes. The following steps will illustrate the process of the CMA for an example intersection, shown in Figure 1, with assigned hourly volumes.

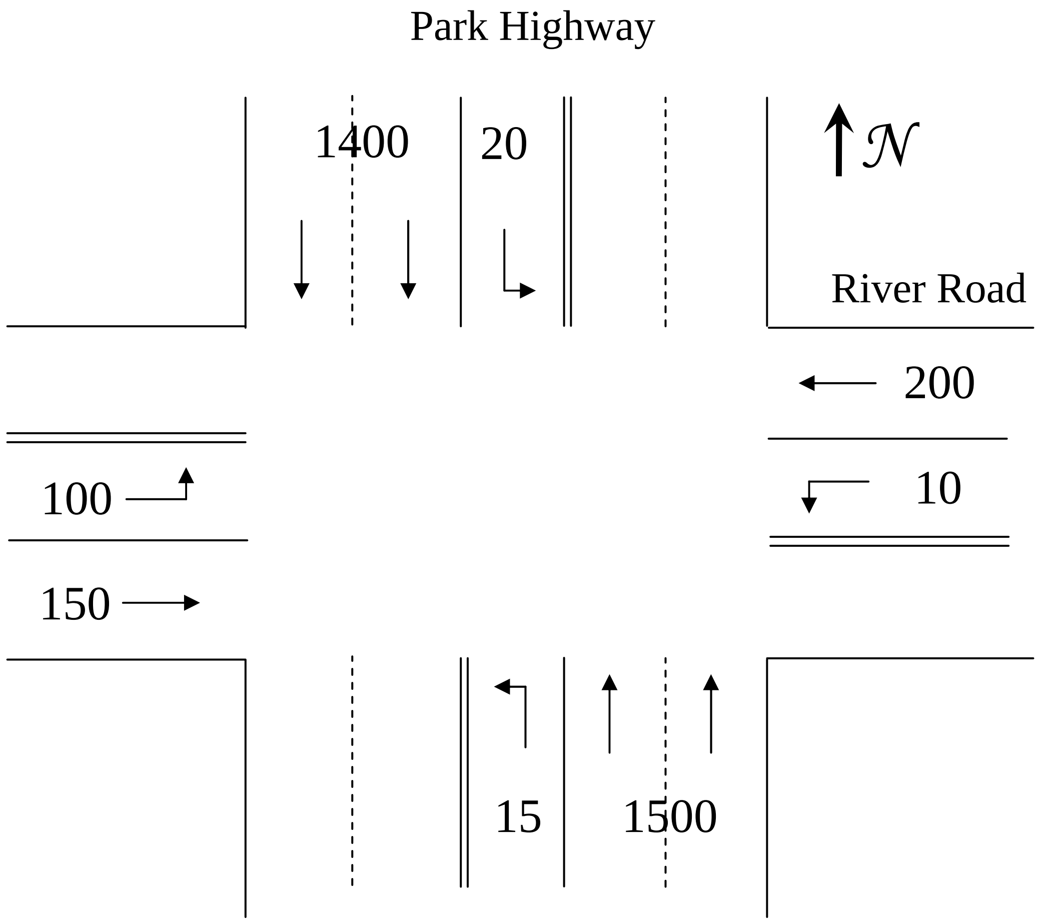


Figure 1: Example intersection.

1. Critical Lane Volumes

This CMA assumes that left turns are protected and that compatible left turns and through movements may be served concurrently. The movement diagram in Figure 2 shows the observed traffic movements for one cycle for this intersection. As shown, the NBLT and SBLT movements are served first. When the NBLT movement traffic has been served, the SBTH movement can be served concurrently with the SBLT movement. The NBTH and SBTH movements can then be served concurrently. The EBLT and WBLT movements are served concurrently and then the EBTH and WBTH movements are served concurrently.

Critical movements are made up of the two movements that may not be served concurrently in a given direction, such as in the North-South direction (movements along the Park Highway in the example) or in the East-West direction (movements along River Road in the example). For a typical four-legged signalized intersection with streets oriented in the four ordinal directions, there are two critical movement volumes, one in the North-South direction and one in the East-West direction. In one direction, such as North-South, there are two possible critical movements, NBLT and SBTH, or SBLT and NBTH.

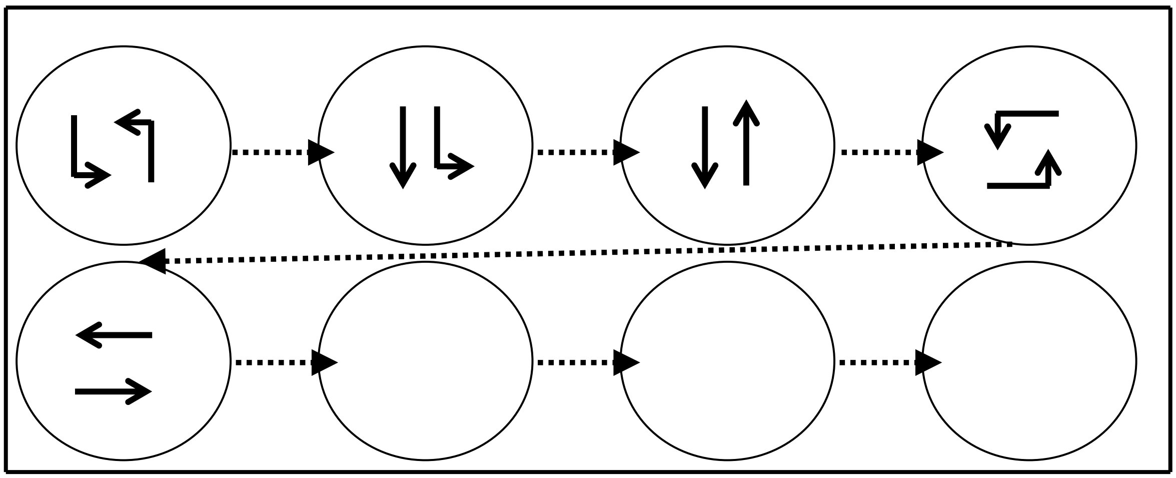


Figure 2: Movement diagram.

a. North-South (Park Highway) Critical Movements

For the example intersection:

SBTH + NBLT = $\left(\frac{1400}{2}\right) + 150 = 850$ vph

NBTH + SBLT = $\left(\frac{1500}{2}\right) + 200 = \mathbf{950\ vph}$

In this case, the North-South critical movement volume is 950 vehicles per hour.

b. East-West (River Road) Critical Movements

For the example intersection:

EBTH + WBLT = $150 + 100 = 250$ vph

WBTH + EBLT = $200 + 100 = \mathbf{300\ vph}$

In this case, the East-West critical movement volume is 300 vehicles per hour.

2. Sum the Critical Movement Volumes

This is the sum of the directional critical movement volumes, in the North-South and East-West Directions.

CS = 950 + 300 = **1250 vph**

3. Peak Hour Factor = 1

The peak hour factor reflects the time distribution of traffic arrivals at the intersection throughout the hour. If traffic arrivals are distributed evenly throughout the hour, the peak hour factor is 1, which is assumed here. With a peak hour factor of 1, the critical sum remains the same.

4. Reference Sum = 1710 vph

The reference sum is the maximum per lane volume that can travel through the intersection. Assume this volume is 1710 vehicles per hour.

5. Initial Cycle Length = 100 seconds

The initial (assumed) cycle length is 100 seconds. The optimal cycle length will be calculated at a later time.

6. Calculate Lost time

The assumed lost time is four seconds per phase. For a typical four-legged signalized intersection with protected left turn movements, there are four phases. Four phases multiplied by four seconds is 16 seconds of lost time.

7. Calculate the Critical Volume/Capacity Ratio for the Intersection.

The following equation is used to estimate the critical volume to capacity ratio. The previously estimated required inputs are summarized in Table 1, below.

$$X_{CM} = \frac{CS}{RS\,(1-\frac{L}{C})}$$

Table 1: Summary of Inputs

Parameter	Value
North-South Critical Movement Volume	950 vph
East-West Critical Movement Volume	300 vph
Critical Sum	1250 vph
Peak Hour Factor	1
Reference Sum	1710 vph
Initial Cycle Length	100 s
Lost Time	16 s

$$X_{CM} = \frac{1250}{1710\ (1 - \frac{16}{100})}$$

$$X_{CM} = 0.87$$

Because the volume/capacity ratio is below 1, there is adequate capacity for the example intersection.

Appendix D: Queuing Systems: Field Observations

Purpose

The purpose of this activity is to observe the process of queuing at signalized intersections.

Learning objectives

1. Describe queuing behavior at signalized intersections.
2. Contrast the D/D/1 queuing with actual traffic flow in field.

Inquiry Questions

1. Were all of the observed cycle lengths the same? Why do you think they are/aren't?
2. If your cycle lengths were different, did you notice a relationship between cycle length and delay?
3. What differences did you notice between queuing in the field and the D/D/1 queuing model? (Hint: compare the queuing diagrams and queue accumulation polygons from this activity to those from Assignment 23.)

Deliverables

Submit the answers to your questions, the diagrams, and the delay/performance estimates for your intersection in an Excel spreadsheet, one per team.

Tasks

For your intersection, record the times that each vehicle arrives into the system and leaves the system for **three** cycles for **one** lane on the assigned approach. Prepare queuing diagrams and compute delay and performance based on the data that you collect.

Task 1: Record the times that each vehicle arrives into the system and leaves the system for **three** cycles for **one** lane using the form shown in Table 3. An example of the results of the data collection for one cycle is shown in Table 2.

- For the assigned approach, watch the traffic flow for several cycles. Observe the queue and how far back from the intersection the queue reaches. The maximum extent of the queue is the furthest point the line of cars reaches back from the stop bar, as shown in Figure 3. This location is the point of maximum queue and will be considered the entry point into the system. The time at which a vehicle crosses this point will be considered the time it enters the system. Two group members should stand at this location to observe and record the times that vehicles enter the system.
- The stop bar, at the edge of the intersection, is considered the exit point of the system. When a car crosses this line it will be considered as exiting the system. Two group members should stand at the stop bar to observe and record the times that each vehicle leaves the system.
- The remaining group members will record the time the signal indication turns red and green (to the nearest second).
- Important: All times should be recorded to the nearest second. Be as accurate as possible because the following tasks rely on the accuracy of your data.

Task 2: Calculate volume and prepare diagrams

- Based on the information you collected, calculate the volume of this lane for each cycle. This is the number of vehicles that crossed the stop bar.
- Plot the arrivals and departures of vehicles for each cycle, as shown in the example in Figure 4. This is the queuing diagram. Observe the variation in queue length between cycles and the variation in delay between individual vehicles.
- Prepare a queue accumulation polygon, labeling all important features.

Task 3: Compute Delay

- Calculate total delay for each cycle. This is the area under the queue accumulation polygon.
- Calculate average delay for each cycle. This is the total delay for each cycle divided by the departure volume for each cycle.
- Calculate average total delay across the three cycles and average delay across the three cycles.

Task 4: Estimate performance

- Using table 7.4 (page 269) estimate the level of service (performance) for this approach.

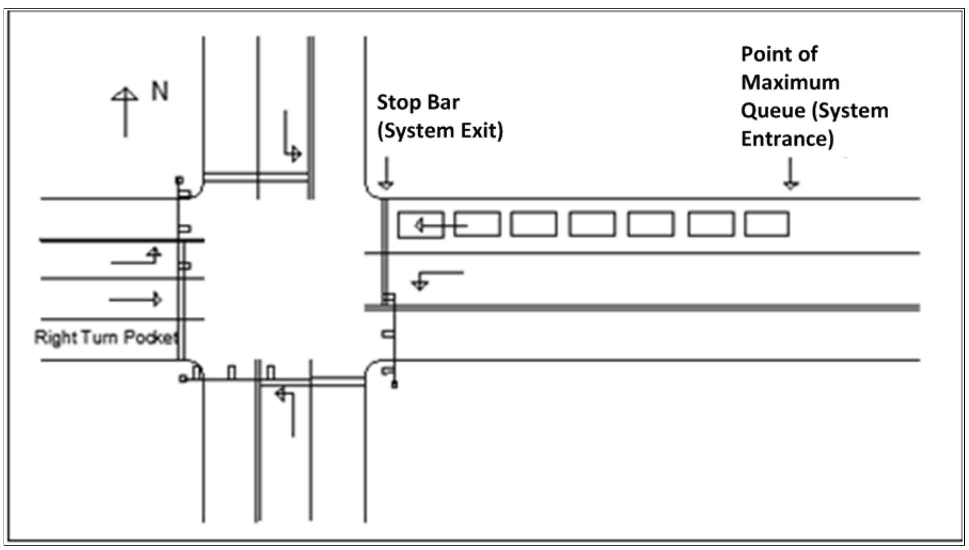


Figure 3: Queuing system diagram.

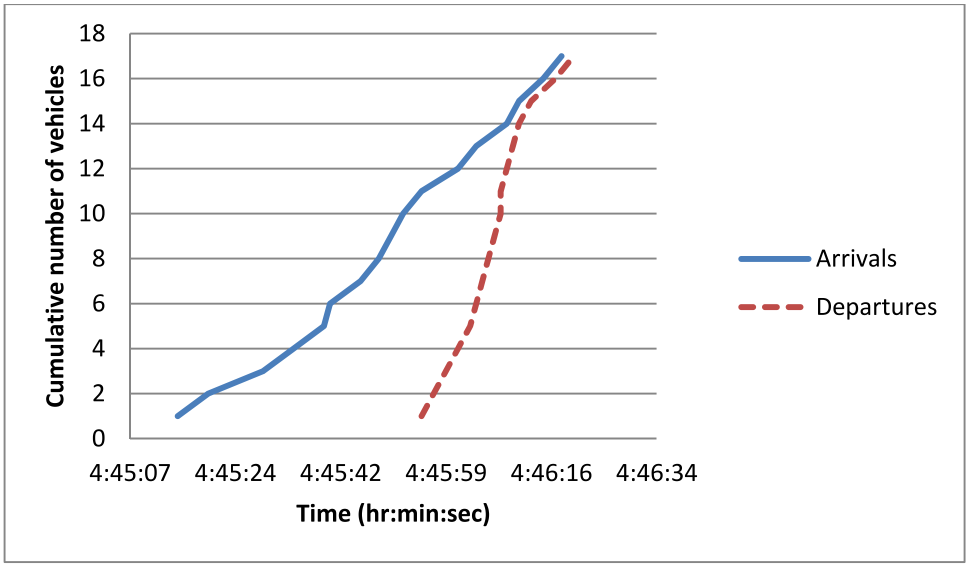


Figure 4: Field queuing diagram example.

Table 2: Data Collection Example

	Cycle 1		Cycle 2		Cycle 3	
		Time		Time		Time
	red	4:45:14	red		red	
	green	4:45:54	green		green	
	Arrival Time	Departure Time	Arrival Time	Departure Time	Arrival Time	Departure Time
1	4:45:15	4:45:55				
2	4:45:20	4:45:57				
3	4:45:29	4:45:59				
4	4:45:34	4:46:01				
5	4:45:39	4:46:03				
6	4:45:40	4:46:04				
7	4:45:45	4:46:05				
8	4:45:48	4:46:06				
9	4:45:50	4:46:07				
10	4:45:52	4:46:08				
11	4:45:55	4:46:08				
12	4:46:01	4:46:09				
13	4:46:04	4:46:10				
14	4:46:09	4:46:11				
15	4:46:11	4:46:13				
16	4:46:15	4:46:17				
17	4:46:18	4:46:20				
18						

Table 3: Data Collection Form for Queuing Activity

	Cycle 1		Cycle 2		Cycle 3	
		Time		Time		Time
	red		red		red	
	green		green		green	
	Arrival Time	Departure Time	Arrival Time	Departure Time	Arrival Time	Departure Time
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
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Appendix E: Pedestrian and Bicycle LOS at an Intersection

Purpose

The purpose of this activity is to estimate the pedestrian and bicycle level of service (LOS) for an intersection based on the intersection geometry and demand characteristics.

Learning objectives

1. Be able to estimate the pedestrian and bicycle LOS using the HCM methodology for a specific intersection based on geometric and demand characteristics.
2. Be able to use the LOS framework to describe the performance of an intersection with regard to pedestrian and bicycle modes.

Required resources

- Stop watch
- Google Earth

Inquiry Questions

3. Which intersection geometric and demand characteristics seem to have the largest effect on LOS for pedestrians? For bicycles?
4. In what way do the different geometric and demand characteristics affect LOS?

Deliverables

5. You will need to have a copy of your completed data sheets, both field data and Google Earth measurements, to discuss in class on Friday, April 6th.
6. You will submit a copy of your summary tables and the LOS score and LOS letter value for pedestrians and bicycles at your intersection and answers to the inquiry questions by Wednesday, April 11th. This work should be contained in an Excel spreadsheet, one copy per team.

Tasks

For your intersection, collect volume, signal control, and geometric data as described below. Use this data to estimate the performance of the intersection with regard to pedestrians and bicycles.

> **Important:** Be sure to collect data for the assigned approach and assigned crosswalk. For this exercise, the street with the assigned street approach is considered the subject road. The LOS equations are provided in Equation 1 and Equation 2; an example intersection is shown in Figure 5 and Figure 6. A full example of the field data collection and calculations is shown later in the document.

Task 1: Collect geometric data for the pedestrian analysis using the pedestrian data collection section of Form 1. Observe traffic on the subject street approaching the crosswalk (on the side the subject crosswalk is on). Record the posted speed limit.

Task 2: Collect volume and signal control data for the intersection for the pedestrian analysis. For eight complete cycles, record traffic counts crossing the subject crosswalk as described on Form 1. The following process should be used for the data collection process.

- Group Members #1 and #2 should stand in a location which allows them to clearly see one vehicle signal head as well as the pedestrian signal head associated with the subject crosswalk. Using a watch, Group Member #1 will call out the time each cycle begins and ends as well as the time the WALK* sign for the crosswalk begins and ends. Group Member #2 will record these times. The walk time is the time associated with the green pedestrian walk indication and does not include the flashing Don't Walk indication. It is important to call out the beginning of each cycle to all the group members for accurate data collection. (Remember, a cycle is a complete sequence, for all approaches, of signal indications.)
- Group Member #3 should keep a tally of vehicles turning right from the subject street (v_{rt}), the number of these vehicles turning right on red (v_{rtor}), and the number of right turning vehicles from the cross street (v_{rtm}).
- Group Member #4 should keep a count of vehicles traveling on the subject street through the intersection both from the side the crosswalk is on and the opposing side of the intersection (v_{th}, v_{tho}) for each cycle.
- Group Member #5 should keep a count of vehicles turning left from the subject street crossing the crosswalk (v_{lt}) and from the cross street crossing the crosswalk for each cycle. It should be noted how many vehicles turn during a protected left turn and during a permitted left turn from the cross street ($v_{lt,prot}$, $v_{lt,perm}$).

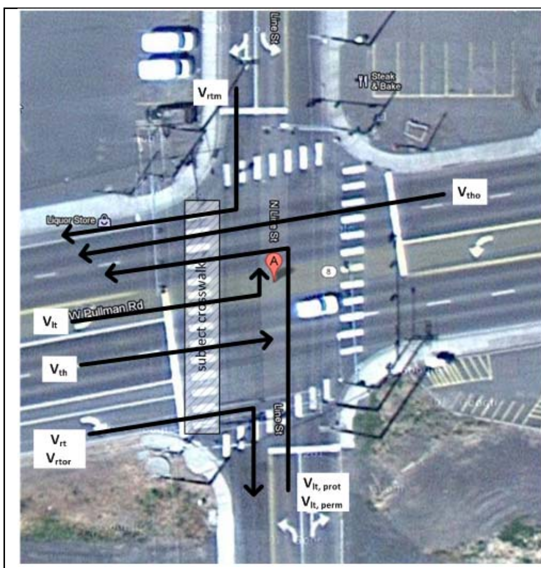

Figure 5. Example intersection with pedestrian variables.

Figure 6. Example intersection with bicycle variables.

*Note: To obtain the pedestrian walk signal data you may need to push the pedestrian button for each cycle. You must collect the pedestrian walk signal data for each cycle.

Task 3: Collect geometric data for the bicycle LOS analysis as described on the bicycle section of Form 1. Record the number of through lanes on the subject approach and the percent of the street parking that is occupied. Observe if a bike lane or curb is present on the approach.

Task 4: Collect geometric data for the bicycle LOS analysis using Google Earth. Measure the bicycle lane width, the outside shoulder width, the width of the cross street from curb to curb, and the width of the bicycle lane, if present. You should record measurements to the nearest 0.25 ft.

Task 5: Using your field data, fill in and complete calculations described in Table 5 for the pedestrian analysis. Fill in and complete calculations described in Table 6 for the bicycle analysis.

Task 6: Using the values from Table 5 and Table 6, estimate the perception index for pedestrians for the subject crosswalk with Equation 1. Estimate the perception index for bicycles for the subject approach using Equation 2.

Task 7: With the perception index scores, estimate the LOS for pedestrians and bicycles for the intersection using Table 4.

Table 4: LOS for Pedestrians and Bicycles at Intersections

LOS	LOS score
A	≤ 2.00
B	>2.00 – 2.75
C	>2.75 – 3.50
D	>3.5 – 4.25
E	>4.25 – 5.00
F	>5.00

Equation 1: Pedestrian LOS

$$PLOS_{int} = 0.5997 + 0.681(N_d)^{0.514} + 0.00569\left(\frac{v_{rtor} + v_{lt,perm}}{4}\right)$$
$$+ 0.00013(S)\left(\frac{0.25}{N_d}(v_{rt} + v_{th} + v_{lt} + v_{lt,prot} + v_{lt,perm} + v_{tho} + v_{rtm}\right)$$
$$+ 0.0401\left[ln\left(\frac{(C - g_{walk})^2}{2C}\right)\right]$$

Where:

$PLOS_{int}$	Pedestrian Perception Index (LOS score for intersection crossing)
Physical characteristics	
N_d	Number of traffic lanes crossed when traversing crosswalk
S	Posted speed limit
Demand characteristics	
V_{rt}	Right turn traffic volume from the subject street that crosses the subject crosswalk (veh/h)
V_{th}	Through traffic from the subject street that crosses the subject crosswalk (veh/h)
V_{lt}	Left turn traffic from the subject street that crosses the subject crosswalk (veh/h)
V_{rtor}	Right turn traffic volume from the subject street that crosses the subject crosswalk during the red indication (veh/h)
V_{rtm}	Right turn traffic from the cross street that crosses the subject crosswalk (veh/h)
V_{tho}	Through traffic from the opposing direction that crosses the subject crosswalk (veh/h)
$V_{lt,perm}$	Permitted left turn traffic from cross street that crosses the subject crosswalk (veh/h)
$V_{lt,prot}$	Protected left turn traffic from the cross street that crosses the subject crosswalk (veh/h)
Signal timing characteristics	
C	Cycle length (s).
G_{walk}	Effective walk time (s) = WALK + 4s

See Figure 5 for an illustration of the above variables.

Equation 2: Bicycle LOS

$$BLOS_{int} = 4.1324 + 0.0153(W_{cd}) - 0.02144(W_{ol} + W_{bl} + I_{pk}W_{os}{}^{*}) + 0.0066\left(\frac{v_{ltb}+v_{thb}+v_{rtb}}{4N_{th}}\right)$$

Where:

$BLOS_{int}$	Perception index (LOS score for intersection approach)
Geometric characteristics	
W_{cd}	Curb-to-curb width of the cross street (ft)
W_{ol}	Width of the outside through lane (ft)
W_{bl}	Width of bicycle lane (ft) (0 if no bicycle lane provided)
I_{pk}	Indicator variable for on-street parking occupancy. (0 if decimal proportion of on-street parking occupied is greater than 0.0, 1 otherwise)
W_{os}*	Adjusted width of paved outside shoulder (ft): • W_{os} – 1.5 (but is greater than or equal to 0) if curb is present • W_{os} otherwise
W_{os}	Width of paved outside shoulder (ft)
N_{th}	Number of through lanes on the subject approach (shared or exclusive). This includes bike lanes
Demand characteristics	
V_{ltb}	Left-turn demand flow rate (veh/h)
V_{thb}	Through demand flow rate (veh/h)
V_{rtb}	Right-turn demand flow rate (veh/h)

See Figure 6 for an illustration of the above variables.

Table 5: Pedestrian LOS Summary Table

Pedestrian Data Demand			Observation Time Period (s)		Vehicle Volume (veh/hr)
V_{rt} (Sum of vehicles over observation time period)		÷		x 3600 s/hr	
V_{rtor} (Sum of vehicles over observation time period)					
V_{th} (Sum of vehicles over observation time period)					
$v_{lt,prot}$ (Sum of vehicles over observation time period)					
v_{rtm} (Sum of vehicles over observation time period)					
v_{tho} (Sum of vehicles over observation time period)					
v_{lt} (Sum of vehicles over observation time period)					
$V_{lt,perm}$ (Sum of vehicles over observation time period)					
Signal Control					
Average C (s) (Sum of observation time/# cycles)					
Average WALK (s) (Sum of WALK time/# WALK intervals)					
g_{walk} (s) = WALK + 4s					
Geometry					
N_d (#)					
S (mph)					

Table 6: Bicycle LOS Summary Table

Bicycle Data Demand			Observation Time Period (s)		Vehicle Volume (veh/hr)
V_{rtb} (Sum of vehicles over observation time period) $V_{rtb} = V_{rt}$ from pedestrian data		÷		x 3600 s/hr	
V_{thb} (Sum of vehicles over observation time period) $V_{thb} = V_{th}$ from pedestrian data		÷		x 3600 s/hr	
V_{ltb} (Sum of vehicles over observation time period) $V_{ltb} = V_{lt}$ from pedestrian data		÷		x 3600 s/hr	
Geometry					
W_{cd} (ft)					
W_{ol} (ft)					
W_{bl} (ft)					
N_{th} (#)					
W_{os} (ft)					
I_{pk} (0 if decimal proportion of on-street parking greater than 0, 1 otherwise)					
If a curb is present: W_{os}^* (ft) = W_{os} - 1.5 If a curb is not present: W_{os}^* (ft) = W_{os}					

Pedestrian Example Problem: Pedestrian Field Data Collection, Calculations, and LOS (Based on example intersection)

Field Data

Geometric Data

N_d	6	S	35

Demand/Signal Control Data

		C	WALK (s)	Subject Street (veh) Vrtor	Vrt	Vth	Vlt	Cross Street (veh) Vrtm	Vtho	Vlt,perm	Vlt,prot
Cycle 1	start	3:43:14	3:44:14	2	3	17	8	6	18	1	4
	end	3:44:55	3:44:20								
Cycle 2	start	3:44:55	3:45:52	4	4	20	7	4	19	2	3
	end	3:46:29	3:45:58								
Cycle 3	start	3:46:29	3:47:33	3	3	19	9	7	21	3	3
	end	3:48:07	3:47:39								
Cycle 4	start	3:48:07	3:49:12	2	4	23	8	6	25	3	4
	end	3:49:52	3:49:18								
Cycle 5	start										
	end										

Pedestrian Data Summary Table **Demand**			Observation Time Period (s)		Vehicle Volume (veh/hr)
V_{rtor} (Sum vehicles over full time period)	11	÷	398	x 3600 s/hr	99
V_{rt} (Sum vehicles over full time period)	14		398		127
V_{th} (Sum vehicles over full time period)	79		398		715
v_{lt} (Sum vehicles over full time period)	32		398		289
v_{rtm} (Sum vehicles over full time period)	23		398		208
v_{tho} (Sum vehicles over full time period)	83		398		751
$V_{lt,perm}$ (Sum vehicles over full time period)	9		398		81
$v_{lt,prot}$ (Sum vehicles over full time period)	14		398		127
Signal Control					
Average C (s) (Sum observation time/# cycles)	99.5				
Average WALK (s) (sum WALK time/# WALK signals)	6				
g_{walk} = WALK + 4s (s)	10				
Geometry					
N_d (#)	6				
S (mph)	35				

From Equation 1, $PLOS_{int}$ = 3.15. This LOS score corresponds to a LOS C, from Table 4.

Bicycle Example Problem: Bicycle Field Data Collection, Calculations, and LOS (Based on example intersection)

Field Geometric data*

% on street parking occupied	N_{th} (#)
0%	3

Observations:

Is there a bike lane on the assigned approach?	Y
Is a curb present on the major street approach?	Y

Google Earth Geometric Data*

Wbl (ft)	Wol (ft)	Wos (ft)	Wcd (ft)
4	12	4	42

Bicycle Data Summary Table Demand			Observation Time Period (s)		Vehicle Volume (veh/hr)
V_{rtb} (Sum vehicles over full time period) $V_{rtb} = V_{rt}$ from pedestrian data	14	÷	398	x 3600 s/hr	127
V_{thb} (Sum vehicles over full time period) $V_{thb} = V_{th}$ from pedestrian data	79	÷	398	x 3600 s/hr	715
V_{ltb} (Sum vehicles over full time period) $V_{ltb} = V_{lt}$ from pedestrian data	32	÷	398	x 3600 s/hr	289
Geometry					
W_{cd} (ft)	42				
W_{ol} (ft)	12				
W_{bl} (ft)	4				
N_{th} (#)	3				
W_{os} (ft)	4				
I_{pk} (0 if decimal proportion of on-street parking greater than 0, 1 otherwise)	1				
If a curb is present: W_{os}^* (ft) = W_{os} - 1.5 If a curb is not present: W_{os}^* (ft) = W_{os}	2.5				

From Equation 2, $BLOS_{int}$ = 5.00. This corresponds to a LOS F, from Table 4.

State Highway 8/Line Street

State Highway 8/Peterson Drive

State Highway 8/Farm Road

State Highway 8/Warbonnet

US 95/Sweet Avenue

6th Street/Deakin Street

US 95/D Street

State Highway 8/Blaine Street

Appendix F: Transit LOS

Purpose

The purpose of this activity is to estimate the transit comfort and convenience level of service (LOS) for Moscow Valley Transit.

Learning Objectives

1. Estimate the relative travel time between riding the bus and another travel mode for selected trips.
2. Discuss how bus service characteristics may affect the quality of a bus rider's experience and affect a person's decision to ride the bus.

Inquiry Questions

1. Did you have a positive or negative experience? Why or why not? Were the bus stop and bus schedule time convenient?
2. Was there anything surprising/interesting about riding the bus?
3. How did factors like the availability of shelter/bench at the bus stop, on-time/late bus service, and travel time affect your experience? How do you think those factors would affect riders' perception in bad weather? How do you think those factors would affect someone who is elderly, does not have a driver license, or someone with a disability?
4. Did you leave your starting point at your assigned time, or did you leave at a later time to reach the bus stop in time to catch the bus?
5. Would you prefer to take transit or to travel by another mode in the future? Is this consistent with the LOS you calculated for the Moscow Valley Transit?
6. Is there a financial cost difference between riding the bus and driving a car? If so, how might that cost affect the decision to ride the bus?

Deliverables

You will submit your travel time differences and your LOS estimate as well as answers to the inquiry questions and your observations in spreadsheet form with your travel partner.

Tasks

You will collect travel time data and observations about traveling by bus and another mode of your choice.

Based on your assigned start time, check the Moscow Valley Transit schedule to decide when you need to arrive at your starting location so that you can arrive at the appropriate bus stop on time. Be ready to travel from your starting point to the bus stop at the appropriate time.

Task 1: Record the time you leave your starting point (this is either leaving your assigned building or your assigned intersection) using the form provided at the end of the lab handout.

Record the time you arrive at the bus stop. Note observations about the weather, the availability of a shelter at the bus stop, and the availability of a bench at the bus stop.

Task 2: Observe the amount of time you wait for the bus and if the bus arrives on time. Record the time the bus arrives at your destination. Observe whether the time you arrive at the destination is consistent with the time the schedule said you would arrive.

Task 3: You do not need to get off the bus, but you should estimate the amount of time it would take you to walk from the bus stop to the door of your destination. Note the estimated time at which you would enter the door at your destination. (You may leave the bus and record the true time you enter the door of your destination. Keep in mind that you will have to wait for the next bus to return to your starting point or to another destination.)

Task 4: Repeat tasks 1-3 for your second starting/ending point (trip 2).

Task 5: When you complete your trips, enter the data in a spreadsheet. Calculate the time it took to travel from your starting points to enter the door of your destination for both trip 1 and trip 2.

Task 6: Use an internet map program (Google Maps, Bing) to get directions from your assigned starting point to your assigned ending point for both trips for car, pedestrian, and bicycle modes and note the estimated travel time for each of these modes.

Task 7: Calculate the difference in the travel time between the bike, pedestrian, and automobile modes and the transit mode. Using Table 7, assign the appropriate LOS value to the travel time difference between the automobile mode and the transit mode for both trips.

Task 8: Record answers to the inquiry questions in your spreadsheet.

Table 7: Transit Comfort and Convenience LOS

LOS	Travel Time Difference (min)	Comments
A	≤ 0	Faster by transit than by automobile
B	1-15	About as fast by transit as by automobile
C	16 - 30	Tolerable for choice riders
D	31 – 45	Round-Trip at least an hour longer by transit
E	46 - 60	Tedious for all riders; may be best possible in small cities
F	>60	Unacceptable to most riders

Trip 1	
Team:	
From ______________________________ To _________________________________	
Activity	Time
Leave Starting Point	
Bus Arrives at Destination	
You arrive at door of destination	

Observations

Bus Stop:

Was there shelter?
Was there a bench? Was it occupied?
How long did you wait for the bus at the bus stop?
Other observations:

On the bus:

Were there enough seats for everyone?
Did you sit next to someone?
Did you have to ride 1 bus or 2 buses to complete your trip?
If you were to ride the bus frequently, do you think you could use your transit time productively?
Other Observations:

Trip 2	
Team:	
From ______________________________ To _________________________________	
Activity	Time
Leave Starting Point	
Bus Arrives at Destination	
You arrive at door of destination	

Observations

Bus Stop:

Was there shelter?
Was there a bench? Was it occupied?
How long did you wait for the bus at the bus stop?
Other observations:

On the bus:

Were there enough seats for everyone?
Did you sit next to someone?
Did you have to ride 1 bus or 2 buses to complete your trip?
If you were to ride the bus frequently, do you think you could use your transit time productively?
Other Observations:

Team #	Team Members	Trip 1	Trip 2
#1	Beckman Clark-Cline	From: BEL 117 To: Walmart	From: F St/Cleveland residential area To: Walmart
#2	Iveson Nufer	From: BEL 117 To: Winco	From: F St/Cleveland residential area To: Winco
#3	Seal Sousa-Mundim	From: BEL 117 To: Safeway	From: F St/Cleveland residential area To: Safeway
#4	Benscoter Combs	From: BEL 117 To: Rosauers	From: D Street/Hayes residential area To: Rosauers
#5	Petersen, M Thomas	From: BEL 117 To: Hamilton Swim Center	From: D Street/Hayes residential area To: Hamilton Swim Center
#6	Larson Brunello	From: BEL 117 To: East City Park	From: D Street/Hayes residential area To: East City Park
#7	McGriff Bradley	From: BEL 117 To: A&W	From: D Street/Hayes residential area To: A&W
#8	Fraser Bailey	From: BEL 117 To: McDonalds on Troy Highway	From: Styner/Hawthorne apartments To: McDonalds on Troy Highway
#9	Hendricks Lorentz	From: BEL 117 To: Gritman Hospital	From: Styner/Hawthorne apartments To: Gritman Hospital
#10	Thome Winkelseth	From: BEL 117 To: 1912 Building	From: Styner/Hawthorne apartments To: 1912 Building
#11	Henrickson Harder	From: BEL 117 To: Jack in the Box	From: 6th Street/Rolling Hills, residential area To: Jack in the Box
#12	Walton Hayden	From: BEL 117 To: Applebee's	From: Styner/Hawthorne apartments To: Applebee's
#13	Sipple Peterson, A	From: BEL 117 To: Latah County Fair Grounds	From: 6th Street/Rolling Hills, residential area To: Latah County Fair Grounds
#14	Millard Seely	From: BEL 117 To: Paris Vision Center	From: Styner/Hawthorne apartments To: Paris Vision Center
#15	Lampert Pena	From: BEL 117 To: Tri-State	From: 6th Street/Rolling Hills, residential area To: Tri-State
#16	Vincent Loucks	From: BEL 117 To: St. Mary's School	From: A St/Cherry residential area To: St. Mary's School
#17	Hanson Hill	From: BEL 117 To: Arby's	From: 6th Street/Rolling Hills, residential area To: Arby's
#18	Herrera Medina	From: BEL 117 To: Walgreen's	From: A St/Cherry residential area To: Walgreen's
#19	VanLydegraf Ramirez	From: BEL 117 To: Moscow Jr. High School	From: A St/Cherry residential area To: Moscow Jr. High School
#20	Eiras Reagle	From: BEL 117 To: University Inn	From: A St/Cherry residential area To: University Inn