CHAPTER 10 – YOUR FINAL DESIGN: PUTTING IT ALL TOGETHER

This chapter includes information that you will need to prepare for, conduct, and assess each of the seven activities included in Chapter 8 of the student activity book Figure 1 shows the various files that are available to support your works as you use these activities, including mini-lecture slides, solution files, and student resource files.

Chapter 10 Your Final Design	Mini-lecture slides	Solution files	Student resource files
A#58 Reading			
A#59 Discovery			
A#60 In Practice			
A#61 In Practice			
A#62 Design			
A#63 Design			

Figure 1. Support files

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

Chapter 10 Your Final Design	A#58 Reading	A#59 Discovery	A#60 In Practice	A#61 In Practice	A#62 Design	A#63 Design
	30 min	60-90 min	60 min	60 min	120 min	30 min

Homework

Mini-lecture

Student discussion

Group work

Figure 2. Activity work

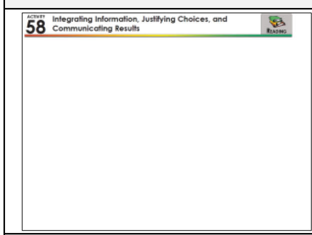
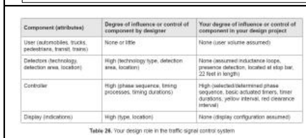
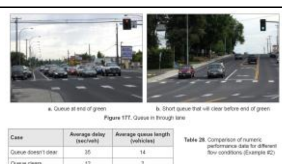
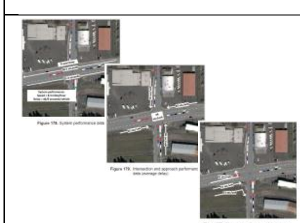
Using Activity #58: Integrating Information, Justifying Choices, and Communicating Results (Reading)

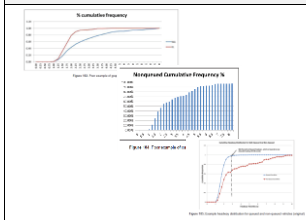
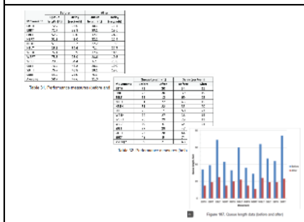
Overview
In this activity, students learn how information can be integrated and communicated.

Options for Use
This activity can be done as homework.

Preparing for the Activity
Read the activity and review the slides.

Doing the Activity (Script)
[Slides: slides58.pptx]
The following slides can be used in the presentation of this activity.

<table>
<tr><th>Slide</th><th>Text</th></tr>
<tr><td>
</td><td></td></tr>
<tr><td>
</td><td></td></tr>
<tr><td>
</td><td></td></tr>
<tr><td>
</td><td></td></tr>
</table>

Slide	Text
	
	
• Use professional language, not student lab report language • Schedule time to write a second draft • Read your writing out loud • Strong lead sentences in paragraphs • What is your story, how does it justify your findings and results, and how does it integrate the numeric and the visual? • Talk to the audience • Use visuals only (primarily)	

Solutions

Included here are:

- Critical thinking questions and answers
- Glossary

Critical Thinking Questions and Answers

1. When we talk about integrating information, what do we mean? Provide an example from everyday life?
2. Identify a kind of information that you often see presented. Describe two effective ways of presenting that information. Why are those ways ineffective?
3. What criteria make for an effective oral presentation? Name at least five, describing how each contributes to the effectiveness of the presentation or report.
4. Why is there not one "right" answer to a problem that you might observe that will apply to all traffic conditions (for example, short or long queues, low or high volumes)? Explain.

Glossary

Level of aggregation	The level at which we collect data or measure performance: for example, movement, approach, intersection, system.
Measure of effectiveness	Measure that describe how well or poorly a system or component is performing.

Using Activity #59: Assembling Information for Your Timing Plan Design (Discovery)

Overview
In this activity, students will be compiling all of the information needed to complete the design report. The purpose of this activity is to allow students to assemble information that they have prepared in previous activities into a form that will help them to prepare their final report and presentation.

Options for Use
This activity can be used in the classroom or assigned as homework.

Preparing for the Activity
Read the activity and identify the key issues for the students to complete.

Doing the Activity
Invite the students to review the activity and answer questions.

Solution
[Excel data file: solutions59.xlsx]
The Excel data files show example solutions.

Using Activity #60: What Do You Know About Signal Timing Design Process (In Practice)

Overview
In this activity, students will learn to write better transportation reports by critiquing professional design reports. The primary purpose of this activity is to allow students to see and critique examples of professionally created design reports. The goal of doing this is to allow students to learn by example. By critiquing the reports, students will gain an understanding of how their results should be presented.

Options for Use
This activity can be assigned as homework or done during a class period.

Preparing for the Activity
Review the example reports and the activity itself.

Supplementary Materials
- Professional reports

Doing the Activity (Script)
Review the activity with the students and lead the discussion about their work.
- Ask students to present what they learned about the professional reports:
    - Describe the report that they read
    - Provide brief critique
    - What aspects of the report will you attempt to model in your design report

Solutions
Review the design report that you have been assigned. Based on your reading, prepare responses to the following questions:
- What were the primary conclusions of the report?
- What were the strengths of the report?
- What were the weaknesses of the report?
- What aspects of the report will you attempt to model in the report that you prepare in Activity #62.

Student responses to these questions will vary depending on the report assigned to their group. The goal of reading these reports is to allow students a chance to learn by example, so following through with a discussion on what the reports did well and did not do well is critical.

Key Issues from Reports
1. What did you learn from the report?
2. What will you attempt to model?

DKS-4th Plain Report

- Goal: improve vehicular travel by reducing travel time, delay, number of stops.
- Deficiencies identified, new signal timing parameters developed.
- Before/after comparisons (for travel time)

KAI-82nd Ave re-timing

- Summary of existing signal timing plan
- Focused on volume data needed for re-timing study
- Recommended time of day plans

Boise CBD (DKS)

- Goal: reducing vehicle delays and stops, creating pedestrian friendly environment
- To accomplish goals: signal timings updated/redesigned
- Performance measures: travel time, delay, stops
- Summarized existing conditions
- Key issues or challenges listed

Arterial Traffic Signal Timing Study (Six Mile)

- Purpose: evaluate existing signal timing, recommended improvements
- Improvements are described
- Impacts of improvements (travel time, delay)
- Goals of traffic analysis (evaluate existing, identify improvements, estimate costs)

Using Activity #61: Signal Timing Design In Practice (In Practice)

Overview
This activity allows students to review their design in the context of the material presented in the Traffic Signal Timing Manual.

Options for Use
This activity is often used in class when instructors can monitor the students' reviews.

Preparing for the Activity
Review previous student results and the relevant sections of the Traffic Signal Timing Manual.

Doing the Activity (Script)
Review the activity with students. Ask them to present their results after they have completed their work. Consider the following issues:

- How did it help to clarify each of the timing parameters?
- What did you learn about recommended values and basis for setting each?
- What is the value of the Traffic Signal Timing Manual in this process for your work?

Using Activity #62: Design Report (Design)

Overview
Students will be preparing a design report and presentation for their intersection giving design recommendations. This purpose of this activity is to have students communicate design recommendations in a written and oral format.

Options for Use
Students will prepare their report over a period of several days.

Preparing for the Activity
Review activity and clarify your expectations for their report.

Doing the Activity
Review the activity with the students, including all of the requirements.

Solutions
Example reports are shown later in this section.

Other Notes

Some Notes From Reading Reports

- Some students equate the passage time to the MAH without accounting for detection zone length, vehicle length, and speed.
- Many students have difficulty in using both their visualizations from observing VISSIM and their numeric data produced from VISSIM.
- Some students don't state their goals that they were trying to meet in their design.
- Too much precision is common error.
- Max out vs. gap out analysis: they still try to balance these two.

General comments on reports:
Design report #1 was reviewed with each group individually to discuss comments and feedback on both the report and the presentation. Here are general comments that apply to some groups (not just one): (1) more careful editing, (2) use your observations/experimental results and don't just rely on the Traffic Signal Timing Manual, (3) your analysis should reflect what you learned from observations (visual from the simulation), (4) combine visual observations with simulation data, (5) what was your goal and what trade-offs did you make, (6) use side by side comparisons to show changes from one case to another, (7) this is a professional quality report and jargon is not appropriate, (8) report should contain details of your results, not just descriptions in your text of these results, (9) how much of a difference is significant from the perspective of the traveler, (10) no more precision than x.x, (11) the role of the computer - it is a tool that you use, among others, (12) note performance at different levels of aggregation (intersection, approach, lane); each tells a different story.

What is the goal, what are the trade-offs. Don't just take information from the TSTM: experiment first, tell me your results, don't just go back to the TSTM as a refuge.

Student questions

- Should I give them example page limits or expectations?
- They should use the experimental results that they obtained with less reliance on the TSTM.
- Is delay the best MOE for this report? It is probably not. Others like percent green utilization or another is probably more appropriate. how would this better fit into the various activities? Or maybe this is a part of the reading for Chapter 11 (!): how do you evaluate intersection performance.
- Creating the world of simulation - focus on this not on what you observe in the field.
- The report requirements should be elaborated on more to give more details on what should be included in each section - but at the same time encourage creativity. (how to do this?)
- I think my separation of "description of final plan" and "evaluation" sections caused some consternation for them; could I organize these sections better.
- [For minimum green time, did I say just look at the manual?]
- Write in a profession manner: don't just refer to a previous activity.
- Definitely need to use chapter 11 reading to talk about what is in a design report, the balance use of their observations, the experimental results, and the TSTM. And, which performance measures to use and what each can tell you. It should refer specifically to the previous activities on which the final report is scaffolded. What is the goal that they are intending to accomplish?
- When they make comparisons between options, they should provide additional detail on why they see "a lot" or "little change".
- Appendix should not just be dumping ground for a "bunch of stuff". Why is it there; how does it support the work presented in the body of the report.
- Goals that should be discussed more: the results of the phase termination analysis (T1 and T2 errors), the goals of max out vs gap out (not to balance them).
- Should I explicitly ask for a description of existing conditions (as the base for all other comparisons).
- (This is really a lab experience for me: what have I learned?)
- How to give them structure, but allow room for creativity?
- Some confusion on relative roles of PT and MinG; these should be clarified; and I can continue to bring some science to the MinG, not just as driver expectancy.
- Should reading SQ be in journal that is checked by the grader periodically and not turned in (probably not).
- How to more effectively compare results (base to final, etc).
- How about performance at different levels of aggregation? Again include this in reading in chapter 11.
- Very little thoughtful analysis - what did you learn?
- Misunderstanding in the weighting of type 1 and type 2 errors in the phase termination analysis, and in the gap out/max out in the max green analysis. I need to be a better job of helping students sort through selecting MAH (this could be done in the reading).
- If I'm going to expect them to show visualizations, relate what they see to the data, etc, then I need to explicitly ask for this and show a rubric in which these items are listed.

Notes from discussion in class today with students on their design report. I found this to be incredibly helpful and should consider this for other activities during the semester. It gives them a change to ask questions that they wouldn't otherwise. Maybe the biggest "ah ha" moment for me was realizing for them that this is not steel design, in which they need to consult a manual for "the answer". There are human factors that must be considered that would never come up in a structures design. This could be written about in the book or in the introduction to the class. Also: (1) Give them a rubric and better guidelines for what should be included in the report, (2) the integration of the "teams of 2" data and conclusions is a difficult and time consuming task, (3) they have little experience with executive summaries and introductions - explain what they are and give examples (like Woodruff example from this semester), (4) this is not steel design as there is not, often, hard and fast and unique answers, (5) use TSTM guidelines properly and not as "the answer".

[Example report prepared by JJ Peterson and Kevin Lewis]
[the following report is intended to serve as a basic example of what each group should be submitting for Activity #62. Each section of the report begins with a short explanation of what should be in the section in [brackets] and is then followed by an example of the writing students should be submitting.]

Executive Summary
[According to http://www.writing.engr.psu.edu/workbooks/design.html#summary, the executive summary is a concise synopsis of the design itself, the motivation for having the design, and the design's effectiveness. The author should assume that the reader has some knowledge of the subject, but has not read the report. For that reason, the summary should provide enough background that it stands on its own. A key difference between an abstract and an executive summary is the target audience. Executive summaries are written to a managerial audience while abstracts are written to a technical audience. Students should write the executive summary treating the professor as the project management.]

The goal of this project was to improve the efficiency and performance of the intersection of State Highway 8 and Blaine Street in Moscow, Idaho by updating the signal timing parameters, in an effort to decrease delay and queue length. The eastbound and westbound through movements were prioritized when make design decisions because they have the highest demand volumes at 440 and 375 vehicles per hour respectively.
Six different parameters were evaluated in the updated signal timing plan. The evaluated parameters were the minimum green time, maximum green time, passage time, yellow time, red clearance time, and left turn treatment.
Overall updating the signal timing plan significantly improved the operation of the intersection and achieved the goal of the project, with delay decreasing for all movements and queue length either decreasing or increasing slightly. The level of service for the intersection is predicted to improve from C to A when the updated signal timing plan is implemented.

CONTENTS

Introduction

[The introduction should briefly introduce the project. The introduction typically includes a picture of the intersection, which can be taken from Google Maps, and a clear goal statement for the project. The introduction can also be utilized to outline the contents of the report.]

The purpose of this report is to present the results of a design project focused on updating the signal timing plan for the intersection of State Highway 8 (SH8) and Blaine Street in Moscow, Idaho, shown in Figure 3. The goal of the project was to improve traffic operations by reducing the delay and queue lengths currently present at the intersection, while maintaining the safety of the intersection. Changes in to the signal timing plan will be evaluated using the traffic microsimulation software VISSIM.

Figure 3: Intersection of State Highway 8 and Blaine Street in Moscow, Idaho

This report will be organized into four sections. The first section is the Description of the Intersection, which describes the geometric layout of the intersection, the current traffic demand at the intersection, and the current left turn treatment. The second section is the Description of the Phasing and Timing Plan, which describes the phasing and timing plans for

both the base case and the final network as well as justifications for each design choice. The third section is the
Evaluation of the Phasing and Timing Plan, which evaluates the performance of the intersection compared with performance of the current timing plan. Finally, the Conclusion will summarize the findings of the study.

Description of the Intersection

[The description of the intersection should describe the geometric layout of the intersection, including the number of approaches, the number of lanes on each approach, and the current left turn treatment. Additionally, the description of the intersection should include the traffic demand for each movement of the intersection and the ring barrier diagram for the intersection.]

The intersection of SH8 and Blaine Street is consists of four approaches, with each approach having a left turn lane and a through/right turn lane, with the exception of the eastbound approach, which has through lane and a separate right turn lane. The lane geometry and the phase controlling the movement in each lane can be seen in Figure 4.

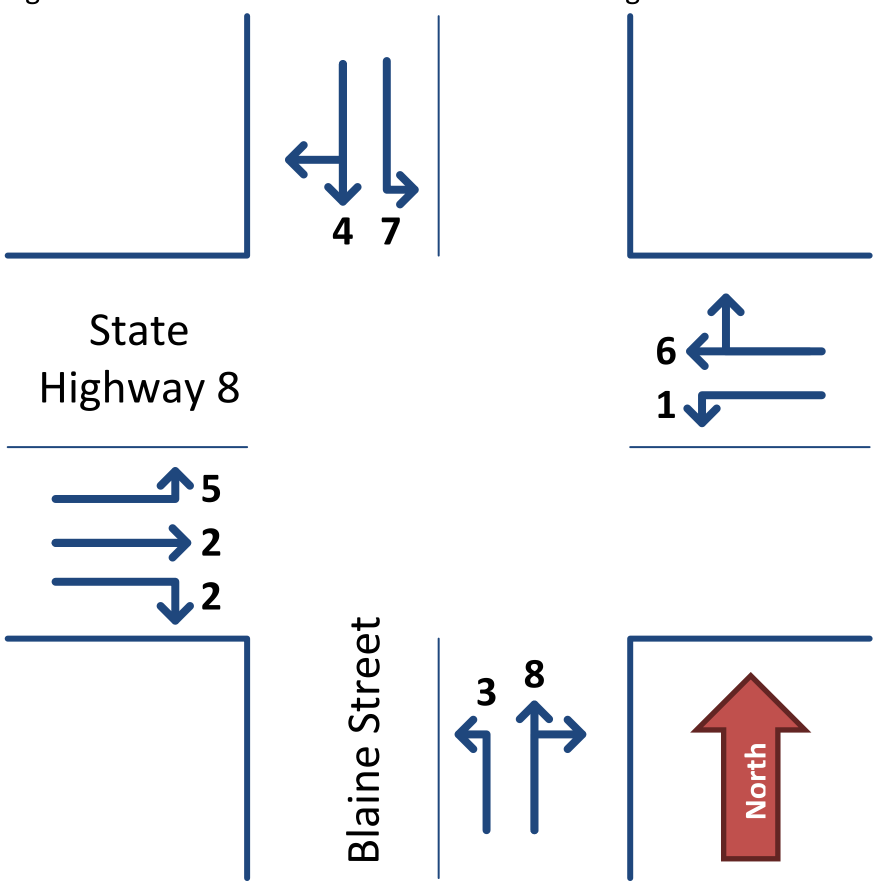


Figure 4: Intersection Sketch Showing Phases Controlling Each Movement

For each approach, the through movement has the highest volume. The movements with the highest demand volumes are the eastbound and westbound through movements on SH8, which have hourly volumes of 440 and 375 vehicles respectively. Demand volumes for each movement can be seen in Figure 5.

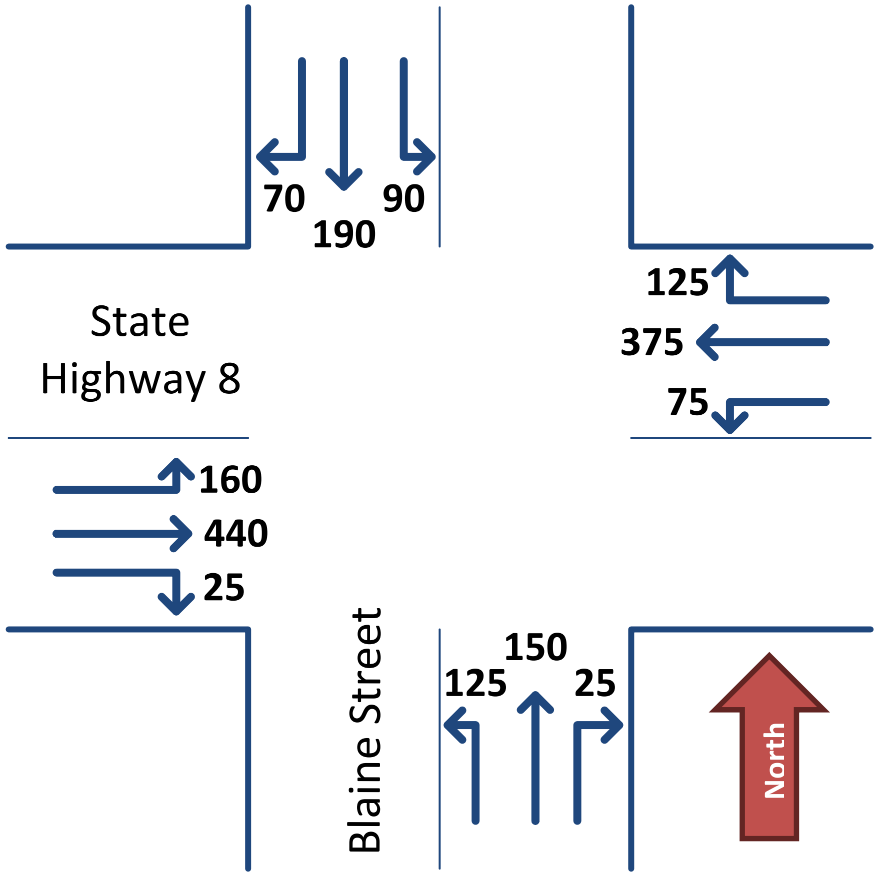


Figure 5: Intersection Sketch Showing Hourly Demand Volumes

The intersection currently operates using eight phases, with protected leading left turns for each left turn approach. Figure 6 shows the ring barrier diagram used to order the phases.

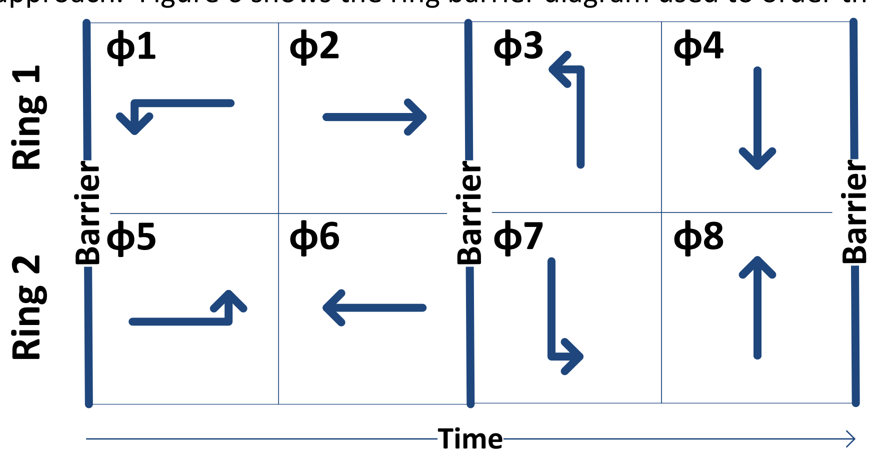


Figure 6: Ring Barrier Diagram

Description of the Phasing and Timing Plan

[The description of the phasing and timing plan should briefly describe the base case timing parameters and the updated signal timing parameters. For each parameter in the final signal timing plan, a justification for why the parameter was chosen should be provided. Examples of the yellow time and left turn treatment will be shown below. Justifications for the other signal timing parameters should also be included in a similar fashion.]

Base Case
The base case signal timing parameters consisted of a minimum green time of ten seconds for through movements and five seconds for left turn movements, maximum green times of 75 seconds for all movements, a passage time of three seconds for each movement, a yellow interval of three seconds, and a red clearance interval of one second.

Minimum Green Time
[The minimum green time was selected in Activity 26]

Maximum Green Time
[The maximum green time was selected in Activity 30]

Passage Time
[The passage time was selected in Activity 26]

Yellow Time
[The yellow time, or vehicle change interval, was set as a result of Activity 39]
The yellow time was calculated using Equation 1, where δ is the reaction time, assumed to be one second, v is the approach speed in feet per second, and a is the deceleration rate, assumed to be 10 feet per second squared. Based on these inputs, the vehicle change interval was set to 3.6 seconds.

Red Clearance Interval
[The red clearance interval was set as a result of Activity 39]

Left Turn Treatment
[The left turn treatment was selected in Activity 35. Although safety is an important factor in selecting a left turn treatment, VISSIM does not have a method to collect safety data, so the safety impacts of left turn treatments were not included.]

If the traffic volumes are low enough to provide sufficient gaps which van be utilized by left turning vehicles, changing the left turn treatment from protected to permitted can significantly decrease delay and queue length by reducing cycle length. However, if the through volume does not provide a sufficient number of gaps, permitted left turns can significantly increase delay and queue length because left turning queues will be unable to clear the intersection. VISSIM tests were completed to compare the effects of changing the left turn treatment from protected to permitted. To do this, the ring barrier diagram first had to be changed to contain only four phases. The updated ring barrier diagram can be seen in Figure 7.

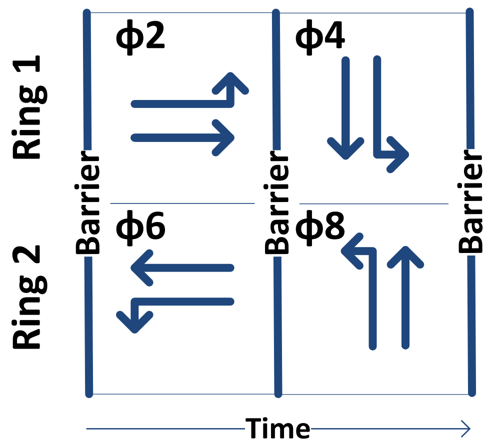


Figure 7: Ring Barrier Diagram for Permitted Left Turns

After the ring barrier diagram was updated, VISSIM was used to collect delay and queue length data for each movement. As shown in Table 1, the delay decreased or remained constant for each movement. Changing from protected to permitted left turn treatment most significantly improved the westbound through and right turn movement, where the delay decreased from 61 seconds to 16 seconds, or from level of service (LOS) E to LOS B, and the overall delay for the intersection decreased from 28 seconds to 10 seconds, or LOS C to LOS A. Additionally, the average queue lengths decreased for each movement. Because both delay and queue length decreased, it is recommended that the left turn treatment be changed from protected to permitted.

Table 1: Delay and Queue Length Comparisons for Protected and Permitted Left Turn Treatments

Movement	Delay (seconds) Comparison			Queue Length (feet) Comparison		
	Protected Left Turns	Permitted Left Turns	Decrease	Protected Left Turns	Permitted Left Turns	Decrease
NBRT	19.9	9.1	10.8	25.9	12.2	13.7
NBTH	19.9	9.1	10.8	24.4	12.9	11.5
NBLT	20.7	9.6	11.1	30.3	18.2	12.1
WBTH	61.3	16.4	44.9	23.6	9.0	14.6
WBRT	61.3	16.4	44.9	21.2	8.5	12.7
WBLT	12.1	2.9	9.2	35.3	16.3	19.0
EBTH	31.6	12.3	19.3	14.8	7.8	7.0
EBLT	22.9	6.8	16.1	30.5	15.8	14.7
EBRT	0.8	0.8	0.0	12.0	11.7	0.3
SBRT	33.8	12.7	21.1	28.3	11.8	16.5
SBTH	33.8	12.7	21.1	26.6	13.2	13.4
SBLT	16.3	5.2	11.1	34.8	15.5	19.3
All	27.9	9.5	18.4	24.0	11.5	12.5

Evaluation of the Phasing and Timing Plan

[The evaluation of the phasing and timing plan should provide comparisons between the base case and the final signal timing plan. Students should be encouraged to include screenshots of VISSIM, illustrating the changes made to their intersection, particularly if the screenshot reinforces that their updated signal timing plan accomplished part of their goal, such as reducing queue lengths.]

When compared with the base case, the final signal timing plan decreased the delay and queue length of all movements, with the intersection delay decreasing from 27 seconds to 10 seconds, or form LOS C to LOS A. Additionally, the queue lengths for most approaches decreased as well, and for the approaches where queue length increased, delay decreased, indicating that vehicles stay in queue for less time. The most significant improvements came in the eastbound and westbound through movements, which were prioritized because they had the highest demand volume.

Table 2: Comparison of Delay and Queue Length for the Base Case and the Final Plan

Movement	Base Case		Final Plan	
	Delay	Queue Length	Delay	Queue Length
EBTH	16.1	30.5	12.3	7.8
EBRT	17.3	30.5	0.8	11.7
EBLT	31.6	19.4	6.8	15.8
NBRT	25.8	31	9.1	12.2
NBTH	25	31	9.1	12.9
NBLT	32.9	12.6	9.6	18.2
WBTH	18.6	37.2	16.4	9.0
WBRT	19.5	37.2	16.4	8.5
WBLT	33.6	13.8	2.9	16.3
SBRT	22.8	30	12.7	13.2
SBTH	21.2	30	12.7	13.2
SBLT	32.7	15.2	5.2	15.5
ALL	21.5	26.5	9.5	11.5

Conclusion

[The conclusion should summarize the results of the project and should state whether or not the goal of the project was achieved.]

The goal of the project was to improve the operation of the intersection by reducing delay and queue length. This goal was accomplished, with the overall LOS of the intersection improving from a C to an A. Additionally, the intersection should be safer because the vehicle change and vehicle clearance intervals have been appropriately set, minimizing the change that a driver will be caught in the decision zone.

Appendix A

[The appendices should present all relevant calculation and data used to select timing parameters. The work done in Activity 44 can be used to create the Appendices.]

Example Student Report

Following is an example student report. Here are my comments and feedback to the students:

1. Excellent executive summary. One of the better examples that I've seen.
2. Excellent writing style and organization.
3. While much of the text is good, I had a hard time verifying your work without presentation of the data and the analysis.
4. Tell us what each table or figure means.
5. Evaluation is complete with thoughtful discussion of results.

Executive Summary

Team Goal Statement:
To design an intersection that efficiently clears the queue and has the minimum possible delay. Methods to do this include allocating only enough green time to clear queue, and reduce wasted green time and delay of other vehicles. We strive to improve the user's experience and safety at the intersection of Sweet Ave. and US 95.

Study Summary:
Currently, this intersection is operating with an average 13 second delay and 19 vehicle queue. The following design parameter changes are being proposed to improve this intersection:

- Lengthen the detection zone to 66ft for all approaches, while reducing the passage time to 0.8 seconds
- Change minimum and maximum green times to 7 seconds and 20 seconds, respectively
- Change the Northbound Left Turn, US 95, from protected to permitted
- Change the yellow and all-red times to 3.5 seconds and 2 seconds, respectively

The recommended improvements are anticipated to have the following impact:

- Reduce average queue length from 19.4 vehicles to 11.6 vehicles
- Reduce the overall delay of the intersection from 13 seconds to 9.8 seconds
- Reduce the average travel time from 29.9 seconds to 27.5 seconds
- Improve the intersection's Level of Service rating from B to A

Introduction
The purpose of this design project is to evaluate the traffic parameters of the intersection of Sweet Avenue and US 95 located in Moscow, ID. From this evaluation it is intended that the intersection become more efficient and safe. During the evaluation, current parameters were measured and then retested using techniques in the *Traffic Signal Operation and Design Manual* and guidelines in *The Traffic Signal Timing Manual.* The parameters investigated include maximum allowable headway, detection zone, passage time, minimum green time, maximum green time, left turns, change interval, and clearance intervals. New parameters were chosen to reduce delay, average queue, and cycle length within the intersection.

Description of Intersection
The intersection of US-95 and Sweet Avenue is a three way arterial intersection serving eastbound, northbound, and southbound traffic. The intersection also serves a parking lot entrance to a Domino's. US-95 southbound is a three lane arterial with two through lanes and a right turning lane to Sweet Avenue. US-95 northbound is also a three lane arterial but with an unprotected left turning lane onto Sweet Avenue. Sweet Avenue eastbound is a two lane arterial with a through lane and a left hand lane. Sweet Avenue westbound is a one lane arterial. Opposite to Sweet Avenue is a Domino's driveway with no lanes.

All roads entering the intersection including the Domino's driveway have signals displayed to them. US-95 southbound has three signal displays, one in front of each through lane and one off to the side on the right. US-95 northbound has four signal displays one in front of each through lane, one off the right, and a special five light display for the left turn lane. Sweet Avenue eastbound has three signals one for each lane and another off to the right. Sweet Avenue westbound for the Domino's driveway has only two signals, one centered and another off to the right.

Motion sensor cameras are mounted on the mast arms above the approach for US-95 north and southbound, and also for eastbound Sweet Avenue. The Domino's driveway does not have any motion sensor camera for its traffic. There is also a cabinet housing the traffic controller and other devices on the northeast corner of the intersection. There are crosswalk signals at all corners of the intersection that allows pedestrian traffic across the US-95 arterials as well as Sweet Avenue.

North and southbound traffic appears to have the highest flow and was favorably served over eastbound traffic. North and southbound was interrupted by traffic in the westbound lane or pedestrian traffic triggering the detectors after a reasonable stopping time. Although it is part of the intersection, westbound traffic's effect on the intersection will be negated during evaluation. Traffic in the north and southbound lanes received a reasonable stopping time in wait for eastbound traffic to clear. Vehicle traffic increased in afternoon with a greater need to serve southbound traffic. Despite the greater amount of traffic, cycle failure did not occur in any of the southbound lanes.

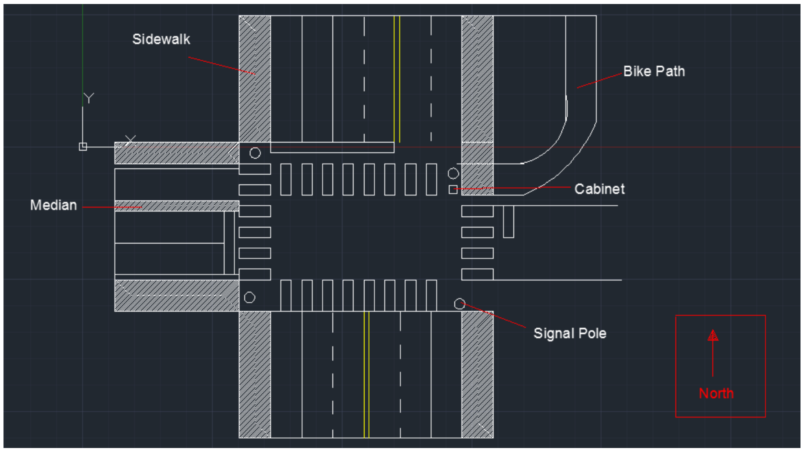


Figure 8: AutoCAD sketch of Sweet Ave and US 95

Phasing and Timing Plan

Base Conditions

The base network and conditions encountered on the intersection of US 95 and Sweet Ave. had minimum green time of 10 seconds for all approaches except the NB LT lane which had a protected left turn green time of 5 seconds. Each approach had a maximum green time of 75 seconds, passage time of 3 seconds, all red time of 1 second, and yellow time of 3 seconds. The detection zone length for each approach had a length of 6 feet.

All of the timing parameters were set up in a VISSIM simulation model and evaluated for a data collection period of 3300 seconds. The data collected were green and red time distributions, average queue and delay for each approach. As well as the travel times for US 95 NB and US 95 SB which was the major street.

Based on the histogram distributions there were a lot of variations of green and red mean times, and it correlated well to how the intersection was designed. US 95 SB and NB had more traffic flow, and therefore phases 2 and 6 had a higher average green time and lower average red time. The average times correlated well with the histograms, in which the average times were located around the peak values of the graph.

Table 3: Base Conditions

Min Green:	10
Max Green:	75
Passage Time:	3
Left Turn:	Protected
Yellow Time:	3
All Red Time:	1
Detection Zone:	6ft

The Ring Barrier Diagram for the base conditions had a permitted left turn lane. Figure 2 shows the base condition diagram for this three-way intersection.

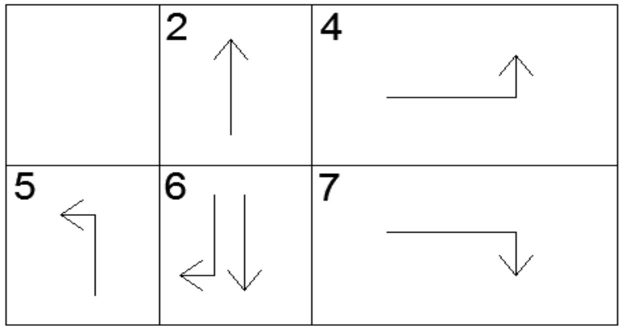


Figure 9: Base Condition Ring Barrier Diagram

With these base conditions, the initial queue and delay data was collected. The delay and queue for each movement direction, as well as the average for the intersection, can be seen below in Table 2

Table 4: Base Condition Delay and Queue

Movement	Avg. Queue (ft)	Delay(sec/veh)
N-S	24.8	13.4
W-S	37	15.2
W-N	22	11.9
W-N	11.6	18.6
N-W	14.7	13.3
S-N	11.1	7.4
S-W	14.4	25.4
All	19.4	13

Maximum Allowable Headway

Using the base network conditions, design values for maximum allowable headway were selected. Through the VISSIM simulation model, headway data for each vehicle on the US 95 SB approach were collected then separated into queued and non-queued groups. Cumulative frequency plots of headways for queued and non-queued vehicles were also prepared. A phase termination analysis was used for the selection of the maximum allowable headway. The phase terminations were categorized into 3 categories, Type 1 where the termination occurs before queue is served, Type 2 where the termination occurs after a non-queued vehicle is served, and Type 3 where the termination occurs after queue is served but before non-queued vehicles is served. Based on the data collected, analyses for the 75th, 85th, and 95th percentile queued headways were completed.

Based on the phase termination analysis spreadsheet template, we determined a maximum allowable headway of 2.97 seconds. This value was derived from the 98th percentile of all the headway values. Compared to the 75th and 85 percentile, the 92nd percentile showed an increased reduction in type 1 termination.

Table 5: Max Allowable Headway

Outcome Summary				
Conclusion	**Percentiles**			
	Optimal (98th)	*95th*	*85th*	*75th*
Headway (sec)	2.97	2.68	2.11	1.98
Error Type 1	6	11	24	26
Good	5	4	3	1
Error Type 2	18	14	2	2

Detection Zone Length

Based on the guidelines in the Signal Timing Manual for basic fully-actuated design, the ideal length of the stop line detection zone is about 80 feet and should not be smaller than 20 feet. This length allows the passage time setting to be small such that the design is very efficient in detecting the end of queue while minimizing the chance of a premature gap-out. Given the option to select between 6 feet, 22 feet, and 66 feet, we chose to select 66 feet, which was the closest to the ideal length for our detection zone.

Passage Time

Using the previously determined maximum allowable headway as well as the detection zone length, the design value for passage time can be computed. In order to set a passage time, we calculated the unoccupancy time. This can be calculated with the following equation:

$$t_u = h - \frac{L_V + L_D}{V}$$

Where t_u is the unoccupancy time, h is the maximum allowable headway found in the last Activity to be 2.97 seconds, L_V is the length of the vehicle (20ft), L_D is the length of the detection zone (66 ft), and V is the local speed limit (25mph, or 36.7ft/s). Plugging in all of these variables gives an unoccupany time of 0.63 seconds. This value is what we use for the passage time; therefore, we calculate a passage time for our intersection of 0.63 seconds. This is essentially zero. The reason this works is because of the long detection zone. The moment that detection zone is unoccupied, the phase will gap out. If there is a gap of 66 feet in the traffic flow, it is pretty safe to say that the queue is cleared. Using this logic, we feel comfortable with our passage time calculation.

Minimum Green Time

Based on guidelines in the Signal Timing Manual for minimum green time, for a particular phase, with stop line detection and a pedestrian button, the only thing that should be considered for setting a minimum green time is driver expectancy. According to Table 5-3, a major arterial with a speed limit of less than 40mph had a minimum green needed to satisfy driver expectancy of 7-15 seconds. Since this is the only factor that should be considered according to the Manual, we decided to set the minimum green time to 7 seconds. Although minimum green time needed to be considered for queue clearance, a quick look at the data showed that queue cleared averaged 25 seconds, with a minimum clearing time of 9 seconds.

If minimum green time is set at 7 seconds, there would be less chance of minimum green extending into non-queue vehicles.

Maximum Green Time

The maximum green time chosen for the intersection was 20 seconds. This maximum green time was chosen after analysis of different max green times from 100 to 10 seconds in 10 second increments. Any maximum green that was 30 seconds or longer rarely gapped out, and had the exact same delay of 10.9 seconds. The results of the analysis showed that at 20 seconds of maximum green time, the simulation gapped out about 90% of the time. The delay associated with the 20 second max green time was 11.1 sec/veh, which was only 0.2 seconds longer than the 30 second (or greater) green time. When making visual observations, a max green time of 20 seconds seemed to clear the queue every time and work well for the intersection. The reason that 20 seconds was chosen was because we wanted the lowest maximum green time that would still clear the queue and almost always max out. We wanted a low maximum green was to reduce the cycle length, which would reduce the delay overall.

Left Turn Treatment

The left turn treatment chosen for this intersection was permitted only. From analysis of delay for protected and permitted left turns, it was found that by changing from protected to permitted timing, the overall delay was reduced from 11.1 sec to 8.2 sec. The delay for the left turning traffic (S-W for this particular intersection) increased quite a bit, almost doubling from 14.5 seconds to 28.6 seconds, which can be seen in the table below. However, the delay for all of the other movements decreases so much that the overall intersection benefits. For this reason, it was decided to change the left turn in to a permitted left turn instead of a protected left turn. Delay and queue data are compared between protected and permitted left turn options below in Table 4.

Table 6: Protected vs. Permitted

Movement	Protected		Permitted	
	Queue (veh)	Delay (s)	Queue (veh)	Delay (s)
N-S	19.7	12.1	9.7	6.8
W-S	33.1	15.2	14.4	9
W-N	18.2	11.4	5	5.7
W-N	5.8	13.4	2.8	7.9
N-W	10.4	11.6	4.3	6.4
S-N	6.9	5.8	7.9	6.6
S-W (LT)	**6.8**	**14.5**	**13.2**	**28.6**
All	**14.4**	**11.1**	**8.2**	**8.2**

Yellow and All-Red Times

The yellow time chosen for this intersection is 3.5 seconds, and the all-red time is 2 seconds. These times were chosen using the formulas found in the Traffic Signal Timing Manual. Calculations can be found in the Appendix. Average values were used for the perception/reaction time and deceleration rate, 1s and 10ft/s^2. Twenty free-flow vehicles were tracked in the VISSIM model, and a cumulative frequency plot of their speeds was constructed. The 85th percentile of speeds was used for clearance calculations, which was 34 miles per hour (see Appendix for graph). An average car length of 15 ft and an intersection width of 85 ft, calculated off of Google Earth, were used.

The new yellow and all-red times increases the delay to 9.4 sec from 8.2 sec, but increases the overall safety of the intersection. One second is not a significant increase in delay, and it is doubtful that drivers would even notice the increase. This small increase in delay increases the safety of the intersection, which was one of our goals.

Final Conditions

The parameter values explained above can be found below in Table 5, which is the resulting intersection that we have modified. The new Ring Barrier Diagram for the changed intersection can be seen in Figure 3. Overall we changed seven different parameters in an effort to reduce delay, travel time, and queue length, as well as maintain/increase safety.

Table 7: Final Configuration

	Base	Final
Min Green (s):	10	7
Max Green (s):	75	20
Passage Time (s):	3	0.6
Left Turn:	protected	permitted
Yellow Time (s):	3	3.5
All Red Time (s):	1	2
Detection Zone (ft):	6ft	66ft

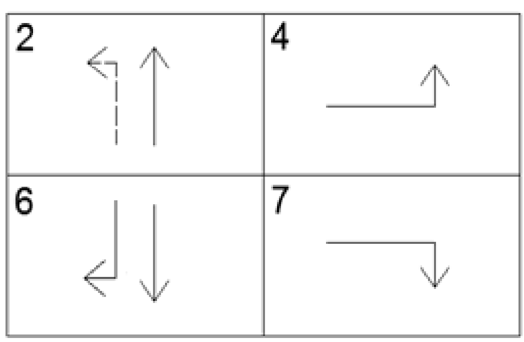


Figure 10: Final Ring Barrier Diagram

Evaluation of Plan

We were able to improve the intersection in all three areas: delay, queue length, and average travel time. The improvements can be seen in the three tables below, comparing the base results to the final results.

Table 8: Queue Improvement

Change in Queue Data		
	Base	*Final*
Movement	Avg. Queue (ft)	Avg. Queue (ft)
N-S	24.8	12.6
W-S	37	25.1
W-N	22	12.3
W-N	11.6	6.1
N-W	14.7	6.6
S-N	11.1	11.2
S-W	14.4	7.4
All	19.4	11.6

Table 9: Delay Improvement

Change in Delay		
	Base	*Final*
Movement	Delay(sec/veh)	Delay(sec/veh)
N-S	13.4	8.1
W-S	15.2	12.9
W-N	11.9	6.8
W-N	18.6	12.3
N-W	13.3	8.2
S-N	7.4	8.2
S-W	25.4	21
All	13	9.8

Table 10: Travel Time Improvement

Change in Travel Time		
	Base	*Final*
Name	Travel Time (s)	Travel Time (s)
US 95 NB	26.5	27.3
US 95 SB	33.2	27.7
Average	29.85	27.5

Overall the changes to the intersection timing plan have decreased the delay from 13 sec/veh to 9.8 sec/veh. This improvement corresponds to an improvement from B to A on the level of service scale. A table showing the different Levels of Service and their associated delays can be seen below in Table 6. The average queue changed from 19.4 veh to 11.6 veh, showing a significant improvement in the efficiency of the intersection. The travel times have changed from 26.5 sec to 26.9 sec in the north-bound direction and from 33.2 sec to 27.1 sec in the south-bound direction. The north-bound and south-bound directions are the important movements through this intersection as they correspond to the major street, US 95, and decreasing the travel time along this major street is an indicator that the intersection is working well.

Table 11: Level of Service Categories

Level Of Service (LOS)	Average Control Delay (seconds per vehicle)
A	< 10
B	> 10 and < 20
C	> 20 and < 35
D	> 35 and < 55
E	> 55 and < 80
F	> 80

The changes to detection zone length, passage time and minimum green time decreased the delay from the initial 13 sec/veh down to 10.9 sec/veh. This improvement is significant, but not enough to change the level of service. The changes have decreased the average queue from 19.4 veh to 13.1 veh. The changes have reduced the travel time from 26.5 sec to 25.6 sec in the north-bound direction and from 33.2 sec to 32.5 sec in the south-bound direction.
The change in maximum green time increased the delay from 10.9 sec/veh to 11.1 sec/veh. This increase is very small, but the change in maximum green time increases the overall efficiency of the intersection in terms of travel time through the intersection along the major street. The change has increased the average queue from 13.1 veh to 13.6 veh. The change to maximum green time has also reduced the travel time from 25.6 sec to 24.5 sec in the north-bound direction and from 32.5 sec to 31.6 sec in the south-bound direction.

The change of the detection zone treatment decreased delay from 11.1 sec/veh to 8.2 sec/veh, improving the intersection from LOS B to A. The change decreased the average queue from 13.6 veh to 9.1 veh. This change also increased the travel time from 24.5 sec to 25.9 sec in the north-bound direction, but reduced the travel time from 31.6 sec to 25.7 sec in the south-bound direction.
The change in yellow and all-red times increased the delay from 8.2 sec/veh to 9.8 sec/veh. Not a significant change and one that still leaves the intersection in LOS A while improving the overall safety of the intersection. The change increased the average queue from 9.1 veh to 11.6

veh. The changes also increased the travel time from 25.9 sec to 27.3 sec in the north-bound direction and from 25.7 sec to 27.7 sec in the south-bound direction.

Using Activity #63: Design Evaluations and Assessments (Design)

Overview
The purpose of this activity is to give students the chance to learn to assess the work of others.

Options for Use
This activity is generally done as part of class as other students are presenting their results.

Preparing for the Activity
Review the evaluation process and decide what you want to do during class.

Doing the Activity (Script)
Conduct the evaluations after the completion of the presentations.