Intelligent Transportation Systems Institute
Center for Transportation Studies
University of Minnesota

Traffic Control
Lessons for High School Students
Lesson Structure
The Intelligent Transportation Systems (ITS) Institute Traffic Control Lessons for High School students is comprised of five lessons, each of 2 to 3 activities. Each activity is designed to take between 15 and 20 minutes. To accommodate varying teacher and class schedules, each lesson may be spread across several class periods. We suggest Lesson 5, “Traffic Data Analysis”, be scheduled for a minimum of two class periods. The lessons get sequentially more complex and detailed, culminating in sophisticated data analysis.

We have also included an addendum that contains suggestions for extended projects featuring problems from the several disciplines that make up the transportation engineering field.

Suggested Sequence
Although there is a clear logical progression, the lessons may be taught individually or out-of-sequence. If there is a limited amount of time, we suggest that Lesson 1 be taught, followed by nearly any lesson or combination of subsequent lessons. The following pairings may be particularly coherent:

- Lessons 1 & 2
- Lessons 1 & 2 & 3
- Lessons 1 & 3 & 4
- Lessons 1 & 4
- Lessons 1 & 5

Synopsis

Lesson 1 – Intro to Signal Timing

Lesson 1 introduces the Traffic Control Simulation. Students explore the simulation by comparing the results of manual versus fixed-time traffic control. Students compare graphs generated by both manual and fixed-time simulations to conclude that fixed time signals control traffic more consistently and with lower queues and delays. The lesson concludes with students following the scientific method to experiment with how altering variables such as offset, traffic volume, traffic speed, and network size affects traffic timing.
Lesson 2 – Intro to Queuing Theory

Following a brief introduction to queuing theory and a discussion on why queues form, students apply the theory’s concepts in an instructor-led simulation. Students graph the data generated by the simulation to determine when queues form, how long it takes queues to dissipate, and identification of the vehicles with the shortest and longest delays.

Lesson 3 – Intersection Analysis

The lesson begins with a discussion around why traffic queues are undesirable and the common characteristics shared by all queues. The instructor then demonstrates with graphs the concept of saturation flow, cycle and phase. Students experiment with different values in a spreadsheet containing D-D-1 properties to determine the best signal timing for a low traffic volume. These values are tested in the Traffic Control simulation and compared with results from other students.

Lesson 4 – Quantitative Experiments

Students design a quantitative experiment using the Traffic Control simulation to determine how altering one or more variables for signal timing and traffic speed impacts traffic flow. Students develop a quantitative hypothesis, then use measurements from the simulation (queue, delay, score, P.I.) and interpretations of relevant graphs to explore specific effects.

Lesson 5 – Traffic Data Analysis

Day 1 - After a brief description of the traffic control technology used in the metro area and throughout the state, students use the MN/DOT’s DataPlot application to examine data from a detector station.

Day 2 - Students compare different variables and determine the relationships between the variables. The lesson concludes with students working in small groups to analyze data from a stretch of highway to identify the optimal time to close a lane for a 1-week project. A role-playing scenario is suggested as a culminating activity in which students present their results as “engineers” to a student panel “city council.”
Correlations with the Minnesota Academic Standards

Through participating in this program, students will develop knowledge and skills that help them meet the following Minnesota benchmarks in science:

**Grade 8 – History and Nature of Science – Scientific Inquiry**

Benchmark 1. The student will specify variables to be changed, controlled and measured.

Benchmark 2. The student will use sufficient trials and adequate sample size to ensure reliable data.

Benchmark 3. The student will use appropriate technology and mathematics skills to access, gather, store, retrieve and organize data.

**Grade 8 – History and Nature of Science – Historic Perspectives**

Benchmark 2. The student will cite examples of how science and technology contributed to changes in … transportation, information processing or communication.

**Grades 9-12 – History and Nature of Science – Scientific Enterprise**

Benchmark 1. The student will compare and contrast the purposes and career opportunities of engineering, technology and science.

Benchmark 2. The student will provide an example of a need or problem identified by science and solved by engineering or technology.
General Equipment Requirements

- Students need access to Internet-connected computers loaded with the following software:
  - Word processor
  - Spreadsheet application
  - Sun’s Java WebStart.
- School proxy servers must allow access to Java WebStart applications.
- Teachers need their own computer workstation complete with digital projector and the following software:
  - Word processor
  - Spreadsheet application
  - Sun’s Java WebStart.

Lesson 1 Materials

For Students:
- Handout (found at the end of this lesson) containing:
  - directions for accessing the Traffic Control simulation, ([http://street.umn.edu/GAME_traffic.html](http://street.umn.edu/GAME_traffic.html))
  - directions for taking screen captures,
  - template for conducting an experiment.
- Computer with Internet connection and Java enabled for each student or small groups of students.
  - NOTE: Students will need the ability to either save or print a word processing document.

For Teachers:
- Computer with projector, Internet connection and Java enabled for the teacher
- “1 x 1 Fixed Time Graph” (found at the end of this lesson and in the Powerpoint presentation included in the teacher materials).

Lesson 2 Materials

For the instructor:
- Stop watch
• Whiteboard
• Green and red white board markers

For students:
• Graph paper and pencils or a spreadsheet program and computer for each student

**Lesson 3 Materials**
For the instructor:
• Computer with projector

For the students:
• Computer with word processing and spreadsheet programs, capable of:
  o reading and working with .xls (Excel) files
  o saving or printing student work
• “Traffic Analysis.xls” spreadsheet loaded on individual computers.

**Lesson 4 Materials**
For the instructor:
• Computer with projector.

For the students:
• Computer with word processing program and the ability to save documents.
• Link to Traffic Control simulation: http://street.umn.edu/GAME_traffic.html

**Lesson 5 Materials**
For the instructor:
• MN/DOT’s Traffic Data Collection Map for either Greater Minnesota or the Metro Area: http://www.dot.state.mn.us/traffic/data/html/collsites.html
Outstate: http://www.dot.state.mn.us/traffic/data/maps/countsites/outstatesites.pdf
Metro: http://www.dot.state.mn.us/traffic/data/maps/countsites/metrosites.pdf
• computer with projector

For the student:
• computer with ability to print or save files, loaded with:
  o Sun’s [Java Runtime Environment](#)
  o word processing software
MN DOT's DataPlot software available free at [http://data.dot.state.mn.us/datatools/DataPlot.jnlp]
Lesson 1: Introduction To Signal Timing

Synopsis
Students work with the Traffic Control simulation to compare controlling traffic manually versus using the fixed-time controls. Students compare graphs generated by both manual and fixed time simulations to determine that fixed-time signals control traffic more consistently, with lower queues and delays. The lesson concludes with students experimenting with how altering variables such as offset, traffic volume, traffic speed, network size affects traffic timing.

Objectives:
- Students will follow the scientific method to conduct an experiment.
- Students will compare graphs generated by traffic patterns to determine whether a fixed or manually timed system is more consistent, efficient and reliable.
- Students will identify how variables such as vehicle speed or network size affect system performance.

Glossary:
The following terms are used throughout the lesson and demarked with boldface. For students with limited exposure to science and math, consider briefly reviewing these terms as they apply to traffic management before beginning the lesson.
- efficiency – a system’s ability to reduce the amount of traffic delay.
- offset - the amount of time that a signal light changes slightly off from the rest of the system or a set difference of time from a central clock.
- queue - a closely spaced collection of vehicles

Activity 1 Materials
For Students:
- Handout (found at the end of this lesson) containing:
  - directions for accessing the Traffic Control simulation, http://street.umn.edu/GAME_traffic.html
  - directions for taking screen captures
  - template for conducting an experiment.
- Computer with Internet connection and Java enabled for each student or small groups of students.
  - NOTE: Students will need the ability to either save or print a word processing document.
For Teachers:

- Computer with projector, Internet connection and Java enabled for the teacher
- “1 x 1 Fixed Time Graph” (found at the end of this lesson and in the Powerpoint presentation included in the teacher materials).

Activity 1 Preparations

- Load the handout found at the end of this lesson onto student machines. You may wish to make hard copies of the handout as well.
- A few days prior to the lesson, test the Traffic Control simulation on each student machine. If the simulation does not run, contact your system administrator and request that proxy permissions are set appropriately for the application to work.
- Ensure that students have the permission to save and/or print documents from the machines they will be using.

Activity 1: Intro to Signal Timing

Students use the Traffic Control simulation to complete several experiments to determine how to create a consistent traffic pattern. To keep track of the experiment results, students will take screen captures of graphs and paste them into a word processing document. They will note the score, Performance Index, and ending queue length.

1. Explain that the objective of a traffic signal network is to manage traffic through a road system as efficiently and consistently as possible.
2. Direct students to the handout and point out how to access the simulation. Direct students to launch the simulation.
3. Give the students time to explore the simulation on their own. They should discover how to adjust the traffic flow settings, pause the simulation, and create graphs.
4. For students who are younger, less able, or more cautious, you may wish to provide additional guidance. In this case, demonstrate the four pull-down menus and how to use them to set the first simulation with the following settings:
   - **high** traffic volume
   - **fast** vehicle speed
   - **1 x 1** network size
   - **mouse click** control type
Additional teacher notes:

- You may wish to remind students that the simulation’s objective is to keep the queue and delay at a minimum.
- The queue length is the number of vehicles waiting at a traffic signal. A long queue indicates inefficient signal timing.
- “P.I.” means “performance index” – a combination of the queue and delay measures. A system that’s performing without any delay or queue will have a PI of zero (0), which is the maximum possible value. In this simulation, the theoretical best P.I. is -0.001.

5. The Lesson 1 handout provides additional instructions and is designed to allow student to progress at their own pace with minimal teacher direction. Depending on the group of students and the teacher’s preference, the teacher may wish to have students stop at the end of Activity 1 or simply continue on to Activities 2 and 3.

6. When they are creating their word processing document with the graph’s screen shot, remind students to type their simulation’s score and ending queue length, then save the file in a place and with a name appropriate for the school’s system.

7. For class discussion, display the “1 x 1, Fixed Time” graph available in the accompanying Powerpoint document. Discuss the pattern displayed in this graph. Does the graph depict a consistent traffic pattern?
8. Ask students to compare their graph with “1x1 Fixed Time” graph. Do the graphs differ? Were they able to maintain as consistent a traffic pattern? Which graph depicts a more consistent traffic pattern? Which graph depicts a pattern with a consistently lower queue? If students used the manual control as directed, their graphs should be less consistent in both the height and spacing of the queue peaks.

**Assessment: Written Reflection**

1. Review points from discussion. If desired, have students to write short answer reflection on these questions.

   - How did changing the number of cars (students) affect how well the intersection was handling traffic flow?
   - What would eventually happen if even more cars started using the intersection?
   - How did changing the signal timing affect traffic?
   - What would result if signals performed inconsistently?
   - Why is a timed system is more efficient, consistent and reliable?
   - Prompt students to save the file.
Activity 2: Fixed Time vs. Manual Control

1. The Lesson 1 handout provides specific directions for the students. Teachers may wish to thoroughly blend Activities 1 and 2 depending on logistical considerations and student abilities. With more advanced groups, you may wish to skip Activity 2 and go straight from Activity 1 to Activity 3.

2. Remind students that the simulation’s goal is to keep delay and queues to minimum, and that they should write the various scores from the simulation (queue, delay, P.I, score) in their word processing document with their graphs.

3. Some groups may need reminders about the scientific method, particularly regarding proper formulation of a hypothesis. Once any necessary background is provided, allow students to proceed with the activity at their own pace.

4. Ask students to generate a graph for the simulation just run and copy it into the same word processing document from Activity 1, as well as the PI and score. Remind them to save the file.

5. Model the scientific method as necessary and direct students to the handout where steps are outlined. Remind students that a hypothesis is nothing more than a thoughtful guess.

6. Discuss with students whether they think it's more efficient to manually operate traffic signals or to program them to operate in a system. Guide students to understand that given the same traffic volume and vehicle speed, a timed system will be more consistent than a manually timed system. This is because a manually-controlled system is inherently inconsistent. An engineered system will remain functionally consistent unless a part of the network fails or the variables for which it was designed change dramatically.

7. Direct students to write up a conclusion for the experiment. Was the hypothesis confirmed?

Activity 3: Variable Experiments

This final activity gives students the opportunity to further apply the scientific method to the Traffic Control simulation. The following experiments may be done with the class as a whole, assigned to smaller groups of students, or given as optional assignments for students to select. Students should continue to follow the scientific method:

- form a hypothesis,
- develop an experimental procedure,
• take notes on their observation and data (including screen captures, system scores, etc.)
• develop a conclusion based on their observation.

Experiment 1: Offsets

• Using the fixed time control and same traffic volume and speed as in the previous activity, demonstrate adjusting the offset for one or more intersections in a 2x2 network to attempt to increase system performance. After students have played a few simulations, discuss: What did “offset” do to the signals? What settings were the most effective for this type of network? Encourage students to refer to their graphs to bolster their argument.
• Have students meet in small groups to share findings and discuss what they consider the best settings and then test others settings in their own simulation.

Experiment 2: Increased Volume or Speed

• Propose changing a variable like traffic volume or speed. How does the change affect system outcomes (simulation score)?

Experiment 3: Increased Network Size

• Propose changing the network size. How does the change affect system outcomes (simulation score)?
Lesson 1: Introduction To Signal Timing

In this lesson you will use the Traffic Control simulation to complete several experiments to determine how to create a consistent traffic pattern. To keep track of the experiment results, you will take screen captures of graphs and paste them into a word processing document while noting various statistics that the simulation tracks, including the score, Performance Index, and ending queue length.

The goal of any traffic system is to maintain a safe, consistent, predictable and efficient environment for drivers. Traffic Control lets you act as a traffic engineer by letting you control signals and traffic flow at multiple intersections. We’ll use this simulation to test a hypothesis and in doing so, develop a better understanding about how traffic engineers use the scientific process to solve every-day problems.

Your teacher will demonstrate how to get started with the simulation and give you a few minutes to explore the controls and features. You can access the Traffic Control simulation by following this link: http://street.umn.edu/GAME_traffic.html

Activity 1: Manual Control

Once you’ve gotten a sense of the simulation, restart the simulation and control it as efficiently as you can until you’ve gotten about 200 cars through a one-intersection grid. This should take just a couple minutes. Pause the action, then create a queue graph by clicking the graph icon.

Take a screen shot of the queue graph and paste it into a word-processing document. Instructions for doing this, if you need them, are in the box to the right.

How to Take Screen Captures:
Use the following keystrokes to capture a graph. You may wish to make the graph larger, even full screen, before doing this:
- PC: press the PRNT SCRN button will copy screen grab to clipboard
- MAC: + + 4 while holding the \( \text{CTRL} \) (CTRL) key will select a portion of the screen and save it to the clipboard.

How to Paste a Screen Capture:
Use the following keystrokes paste a screen capture into this or another word processing document:
- MAC: + V to paste into word processing document
- PC: CTRL + V to paste into word
In your document, note your score, ending queue length and Performance Index (P.I.), then answer the following questions:

1) How consistent is your pattern?
2) What is the longest queue you created?
3) Compare your graph to the 1 x 1 Fixed Time graph that your teacher will display. Which is more consistent? Why?

Save your document for later use.

**Activity 2: Fixed Time vs. Manual Control**

Now it’s time for an experiment. The simulation allows you to select either manual control or fixed-time control. We’re going to compare which provides the better system. Remember, a better system is one that is more efficient and consistent. You are going to compare a fixed-time system and manually-controlled system for the same network. In this activity, you will follow a given procedure. In Activity 3, you will have the opportunity to create your own hypothesis and experiment.

**Hypothesis: What will you test?**

A fixed-time system will be more efficient and consistent than a manually controlled system as evidenced by comparing queue graphs for the two systems.

**Experiment Procedure:**

1) Set up a 2 x 2 network, high volume, fast speed, using manual control. Run the simulation controlling it manually via mouse clicks. After a few minutes, pause the simulation and create a queue graph as you did earlier. Take a screen shot and paste the graph into a new word processing document. Record your maximum queue length, score and P.I.
2) Once you’ve saved that graph, start the simulation again. This time, use a 2 x 2 network with high volume, fast speed and fixed-time control. The simulation will run on its own.
3) After about two minutes, pause the simulation, create a queue graph, and save it to the document with a record of queue length, score and P.I.

**Observations & Results**

In the document, answer the following questions:
- How do the two graphs compare?
- Did the results from the simulation confirm or contradict the hypothesis? How do you know?
Conclusion

Write a one-paragraph conclusion for this experiment, and save your document.

Activity 3: Variable Experiments

Now it’s time for you to design and perform your own experiment with the simulation. Your teacher will explain the concept of “offset” and show you how to control it in the simulation. Then it’s all up to you! Create a hypothesis, design an experiment to test the hypothesis, then create whatever graphs you need to confirm or contradict the hypothesis. Finally, write a conclusion.

You can use whichever variables you wish (e.g. offset, volume, speed, network size), but try to make your hypothesis true-to-life and meaningful.

Create a new document for this activity that includes your hypothesis, the graphs you create, your data (e.g. score, P.I.), your observations and your conclusion.

The template on the next page may help you.
Following the Scientific Method

Use these headings and questions as a template to develop an experiment using Traffic Control simulation.

Hypothesis: What will you test?
In a sentence, state the idea you will test:

Experiment Procedure:
List the variables you will use and the steps you will follow to test your hypothesis:

Observations and Results:
Paste and label screen captures of graphs here. Include any observations you make:

Conclusion:
Did the experiment confirm your hypothesis? State what you can conclude from the experiment:
Lesson 2: Introduction to Queuing Theory

Synopsis
The lesson begins with a discussion on why queues form. Following a brief introduction to queuing theory, students apply the theory’s concepts in an instructor-led simulation. In the final activity, students graph the data generated by the simulation to determine when queues form, how long it takes queues to dissipate, and to identify the vehicles with the shortest and longest delays.

Objectives:
- Students will identify how queues form.
- Students will graph data to determine how long it would take a queue to dissipate.

Glossary:
The following terms are used throughout the lesson and demarked with boldface. For students with limited exposure to science and math, consider reviewing these terms with students before beginning the lesson.

- **cycle** - the length of time from a sequence's beginning to its end.
- **dissipate** – to clear
- **phase** – the portion of a cycle devoted to servicing a given traffic movement.
- **queue** – a closely spaced collection of vehicles
- **service** – when vehicles are allowed to cross the intersection

Materials & Preparation:
For the instructor:
- Stop watch
- Whiteboard
- Green and red white board markers

For students:
- A computer and spreadsheet program for each student or graph paper and pencils if computers are not available.
For Activity 1:
- Check to make sure red and green markers are available for using on the board.
- Consider drawing the chart outlines as described below prior to the lesson.

For Activity 2:
- Prepare a table with three columns: **# of students | time to queue | time to dissipate** such as the one below. Write the numbers 1 – 5 in the first column.

<table>
<thead>
<tr>
<th># of students</th>
<th>Time to queue (seconds)</th>
<th>Time to dissipate (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Activity 1: Introduce the phenomenon of queuing:**
In this part of the activity, students will form lines and experience how queues form and dissipate. It’s important to emphasize that departure rate must be greater than arrival rate or the system will become "saturated" and delays will occur.

1. Show slides with images of queues from the teacher’s presentation.
2. Discuss queues in students’ daily experience. It may also be helpful to know that in Great Britain, the word “queue” is used far more commonly than it is in the United States with phases like “queue up” and “standing in queue.” Questions like the following may help with the discussion:

- When have you waited in line for something?
- Did you ever stop to wonder why lines form?
- Why do you sometimes have to wait in line to order a sandwich?

3. Students should recognize that lines form because supply can't keep up with demand. In the case of traffic, this means that if more people or vehicles arrive than can depart at a given time, then queues begin to form.

4. Describe that in engineering terms, traffic signals operate in phases: red and green. A cycle is the completion of both a red and green phase. For purposes of simplicity and clarity, the yellow phase will be considered part of the red phase in this discussion. Drawing the following diagram on the board may be helpful.

5. Recognize that queues form when traffic flow is stopped by a traffic signal. The challenge for engineers is to time the signals in a way that ensures all vehicles are serviced (can cross the intersection) before end of the green phase.

6. Explain concept of constant arrival rate. Draw or display a chart that describes traffic arriving at an intersection at a steady speed and equal intervals. Point out that this rate is the intersection’s constant “arrival rate”: the rate of arrival that is expected if all vehicles traveled at the same speed and with the same distance between them.

7. Explain that during a red signal phase, since vehicles cannot depart from the intersection, a queue forms. When the signal green phase begins, the vehicles depart at the highest rate the system can provide, the saturation flow rate. Once the queue is cleared, the
departure flow rate is equal to the arrival flow rate.

8. Explain that to find out if the planned arrival rate is correct, we need to figure out how long it takes the resulting queue to form as well as how much time passes before the queue clears. The following demonstration in Activity 2 will help students understand this concept.

**Activity 2: Queuing Demonstration**

1. Conduct this demonstration to help students better understand how long it takes queues to form and dissipate or clear. Using students as the vehicles, you will create a controlled intersection. Students will gather data necessary to graph the phases of a traffic signal.

2. For this demonstration, you’ll need plenty of space and four volunteers. One will be the “timer” who will operate a stopwatch. Another volunteer will act as a “traffic signal”. Two others will act as counters to keep track of the number of “vehicles” entering the intersection and the number leaving the intersection. You may wish to mark out an intersection on the ground with chalk or masking tape.

3. Explain that students are to think of themselves as a vehicle in a traffic system. The volunteer acting as a “traffic signal” will at some point stop the flow of traffic to create a queue. The timer will keep track of how long it takes cars to arrive and the resulting queue to dissipate.

4. Direct the “traffic signal” and “timer” to move to the middle of the room. Explain to the “traffic signal” that when the first student arrives, they are to say “stop”.

5. Once the “traffic signal” is ready, direct the “timer” to start the stopwatch. Send 5 students at different intervals down to the traffic
signal. Remind students that in a system, such as a road, they would follow behind others at a fairly steady pace.

6. Direct the “timer” to call out the time when each student reaches the “traffic signal”.

7. Write down the times as the timer calls out in the “time to queue” column.

8. After the last student has stopped, ask the “timer” to stop the stopwatch. Ask the class to predict how long it will take for the queue to **dissipate** or clear if each person left at a fairly uniform speed.

9. Write the predictions on the board outside of the table and then direct the timer to start the stopwatch as soon as the “traffic signal” says “go.” The timer calls out times as each student leaves the queue and stops the stopwatch after the last person leaves the queue.

10. Add these times to the “time to dissipate” column.

11. Discuss results. Did it take more or less time than you anticipated?

12. Now start the demonstration again, but with all of the students as vehicles (except those with the roles of timer, traffic signal or counter). Instruct the “traffic signal” to announce “go” and “stop” at 5-second intervals. Direct the line of traffic to move along steadily. The pace should be such that the queue may not entirely dissipate before the signal turns red. Counters should continue to keep track of the number of “vehicles” entering and leaving the intersection.

13. Once all students have passed through the intersection and data has been recorded, move on to Activity 3 where you will lead the students in graphing the data.
Activity 3: Graphing the Data

1. Review concepts of phase and cycle.

2. Above the bar diagram on the board or on the projector, begin to draw a cumulative frequency chart. Label the y-axis “cumulative vehicles” and the x-axis “elapsed time”.

3. Note that the traffic signal’s cycle began at $t = 0$ seconds. Demonstrate how to chart the data points for queue formation column. First, mark for when the first vehicle started the queue. Then continue to add marks at which point in time each vehicle entered the queue. It may help to use red ink to establish a visual connection between the signal phase and the data.

4. Chart the data points in the queue dispersal column, preferably in green.

5. Ask students to study the chart and reflect on the story the data tells. Possible questions include:
   - Were the vehicles able to exit the queue before the end of the green phase?
   - What happens to the line of vehicles during the red phase? When does the queue reach its maximum length? Why?
   - Why might queues continue to form even after the cycle phase shifts to green?
   - What would happen at a traffic signal if twice the number of cars were in the system? What might the chart look like?

6. If desired, repeat the activity with different traffic timing and have students create appropriate data tables and graphs.
**Additional Assignment:**

- Ask students to review their graph and then draw a graph for a signal that might have a green phase that is too short?
- What does the graph depict? Answer: queues would never fully disperse.
Lesson 3 – Intersection Analysis

Synopsis
The lesson begins with a discussion around specific reasons that traffic queues are undesirable and the common characteristics shared by all queues. The instructor demonstrates with graphs the concept of saturation flow, cycle and phase. Students then experiment with different values in a spreadsheet containing traffic flow properties to determine the best signal timing for a low traffic volume. These values are tested in Traffic Control and compared with results from other students. The lesson concludes with students repeating the experiments for medium and high traffic flows.

Objectives:
- Students will adjust variables to determine an optimum vehicle queuing and delay.
- Students will describe how increasing or decreasing a variable affects a solution.

Glossary:
cycle - the length of time from a sequence's beginning to its end.
D-D-1 - “D” refers to determined number of arrivals and departures at a single intersection. “1” refers to a single lane.
flow – the number of vehicles passing a point in space over a specified unit of time.
property - characteristics or attributes of an object, number, or system
phase – the portion of a cycle devoted to servicing a given traffic movement.
queue – a closely spaced collection of vehicles.

Materials
For the instructor:
- Computer with projection screen

For the students:
- Computer with word processing and spreadsheet programs, capable of:
  - reading and working with .xls (Excel) files
  - saving or printing student work
- “Traffic Analysis.xls” spreadsheet loaded on individual computers.
Preparation

**IMPORTANT:** Check if the Traffic Control simulation application will run on student machines. If not, check with your system administrator to provide proxy permissions for the application to work.

Make sure the spreadsheet has been loaded on individual computers.

NOTE: If you are teaching this lesson immediately after Lesson 2: Introduction to Queuing Theory, then you might consider skipping the first activity. However, it’s important that you draw the graphs in the first activity for use in this lesson’s second activity.

**Activity 1: Review Queuing & Signal Timing**

1. Discuss why traffic queues are undesirable and problematic, apart from simply being an annoyance. Why should they be avoided?"
   Answers include:
   - Queues increase pollution and smog
   - Queues increase fuel consumption
   - Queues mean more cars packed into smaller areas, increasing the risk of crashes.
   - Queues impact driver concentration: as queues get longer and people are delayed, more drivers are willing to take risks that could cause crashes.

2. Review the concepts **cycle** and **phase**.

3. Note that all traffic queues share similar properties or characteristics. To time signals to reduce the likelihood of a prolonged queue occurring, we need to know a few things:
   - The vehicle arrival rate
   - The vehicle departure rate
   - The time during a green signal that is actually used by traffic (effective green time). Point out that some time is lost during a green signal to a driver’s delayed reaction to the signal change and as well as acceleration.
   - The time during a red signal that traffic is actually stopped (“effective red time”).
   - The total time that has elapsed or “transpired”.

4. Review concept of **flow**, the number of vehicles passing a point in space for per minute or hour.”

5. Draw or display a chart that shows the arrival flow of a hypothetical intersection such as those on the following page.
6. Point out the y-axis and describe flow as the rate at which vehicles are entering a system, in this case an intersection. Make sure that students notice that flow occurs across time.

7. Explore different scenarios and how they would appear on a graph like this. It may be helpful to include a red/green indicator bar underneath the graph. The following examples could be used:
   - A line from the y-axis that’s parallel to the x-axis would indicate a steady arrival rate, the arrival flow at an intersection with a green signal.
   - A line sloping downward from positive flow to zero would indicate a light turning from green to red.

8. Examine more complex and realistic scenarios that include the whole cycle or more than one cycle. For example, what happens to traffic flow and what does the graph look like once the signal switches to green?

   Answer: the traffic would depart at what’s called the “saturation” point – the greatest number of vehicles that the intersection could handle (also called “service”).

9. Note that once the queue dissipates and for the duration of the green signal, traffic would continue to flow into the intersection at the arrival rate.

10. Have students independently graph two continuous cycles of a typical intersection based on their observations of real driving situations. Encourage them to be realistic, and remind them that in a real situation, all lines on the graph will not necessarily be horizontal or vertical. Discuss the graphs as a group.
**Activity 2: Intro to Traffic Analysis**

1. Remind students that engineers use timed signals to make the system more consistent, reliable and efficient. However, they don’t just guess and see what happens. So how does an engineer go about programming a traffic signal?

2. Review graphs from this lesson’s first activity and point out that to properly time the signal, an engineer would need to know the following data:
   a. Arrival rate – how many vehicles are entering the intersection.
   b. Departure rate – how many vehicles are leaving the intersection.
   c. How much time during the green phase vehicles are moving (called **effective green**)
   d. How long the red **phase** lasts when vehicles are stopped (called **effective red**).

3. To start with, focus on arrival and departure rates. Knowing how many cars arriving and departing allows us to monitor whether the traffic timing is working. If fewer cars are departing than arriving, then we know that cars are getting stopped - that something is causing cars to move through the intersection at a lesser rate than we would normally expect.

4. Ask students to guess the capacity of a single lane, the number of vehicles a single lane would normally be able to carry in hour. The accepted standard answer is 1800 vehicles/hour. This is the departure rate since we would not expect anything to slow this down after the traffic light.

5. Remind students that the simulations settings for traffic volume are Low, Medium, High. These are arrival rates and correspond to the following numerical values.
   - Low = 400 vehicles per hour
   - Medium = 600 vehicles per hour
   - High = 800 vehicles per hour

6. Because we know the expected departure rate (1800 vehicles an hour) and can select known arrival rates (400/600/800 vehicles an hour), we can use a set of formulas to conduct a "D-D-1" analysis to help us predict how successful timings will be for the different arrival rates.
D-D-1 stands for ....

D: we’ve determined the arrival rate (number of vehicles/minute).
D: we’ve determined the departure rate (number of vehicles/minute) – 400 or 600 or 800.
1: we know we’re working with just one lane in each direction, without left-hand turns.

7. Display the “Traffic Analysis” spreadsheet. Students won’t actually have to use the formulas to figure out how to time an intersection. Instead, they can use the spreadsheet and plug in values for the arrival and departure rates as well as the effective green and effective red times. Only the yellow cells should be changed by the users. Other cells are calculated by formula. The formulas are all written in their symbolic form in the descriptor column. More advanced students may also be interested in viewing the formulas as they are programmed into the spreadsheet. This is easily done by clicking on the appropriate cell and looking at the formula bar in the spreadsheet program. The various parameters and calculations are described below:

a. Traffic Volume: User input. Set as Low, Medium or High in the simulation, corresponding to arrival rates of 400, 600 and 800 vehicles per hour.
b. Number of seconds for N-S green signal: User input. In a fixed time system, the time that the N-S light is green.
c. Number of seconds for E-W green signal: User input. Same as above but for the cross streets. N-S and E-W green signals do not need to be equal. However, note that the simulation does not allow different flow rates to be used for the different directions.
d. Traffic Volume: Same as the value input above.
e. Number of departures: In this simulation, the number is fixed at 1800 vehicles per hour, the ideal departure rate for one lane.
f. Arrival rate: Same as “Traffic Volume,” but per second instead of per hour.
g. Departure rate: Same as “Number of Departures,” but per second instead of per hour.
h. E-W effective green: User entry from E-W green time
i. E-W effective red: User entry from N-S green time. This is accurate since we are not using a yellow signal phase.
j. Time from start of effective green until queue dissipates – tc: Time in seconds that it takes the queue to dissipate after the light turns green.
k. Proportion of cycle with queue: This property is an indicator of system performance. If greater than 1, then a delay is building up past the cycle, which would indicate that the system is failing.
I. Time to queue dissipates: indicates how long the queue will take to dissipate or clear. One wants to make sure this property is shorter than the effective green time.

m. Proportion of vehicles stopped: This property describes how well the system is operating. It gives an indication of queue size.

n. Average vehicle delay per cycle: This property provides an estimate of how long most vehicles will be delayed in a queue.

8. Direct students to enter 400 for traffic volume (the “low” – 400 vehicle setting in the simulation) and then experiment with adding or subtracting to the E-W green and effective red values. Remind students to pay attention to the values generated for the different properties.

9. After a period of experimentation, discuss how the values for the properties change as the signals timings change. How did just changing the E-W green value affect a queue? How about just changing the N-S? Was there a combination that got the best results? Multiple columns of values are included in the spreadsheet so that students can easily compare multiple scenarios.

10. Based on time allowed, encourage students to experiment to find the combination of signal timings that they think are the best combination of values.

11. Follow the activity with a discussion. The following questions may help guide the discussion.

• What is meant by “best combination of values?”
• How would a real situation, differ from this experiment?
• What else would an engineer need to consider to make this work in reality?
• How would an engineer allow for some of those reality factors in their formulas or design?
Activity 3: Applying D-D-1 Analysis

1. This activity follows directly from Activity 2 and asks students to test their settings in the simulation.

2. Launch and display the Traffic Control simulation. Set the network settings to low volume, slow speed, single size (1x1) and fixed-time control type. If necessary, remind students how to set up the signal timing, pause the simulation and generate a graph.

3. Direct students to take a screen capture of each graph and paste into a word processing document like they did in Lesson 1. The document should include the settings used to create the graph.
4. Ask students to print their word processing documents and meet in small groups to compare results. Did they get what they expected? Which settings generated the best result? How do they know?

5. The following key points should be addressed either in the discussions, by direct instruction, or through other activities:
   • An effective traffic pattern would have a consistently low vehicle delay and a consistent queue length.
   • Queues form when traffic flows stop.
   • The time it takes a queue to dissipate is crucial to determining how long to time a signal.
   • If we can determine the departure flow and arrival flow, we can determine how long to time a signal.
   • Offsets are used to keep traffic flowing across intersections.
   • Engineering is not about finding the single correct answer but rather the solution that best solves the problem.
Lesson 4 – Advanced Work with Variables

Synopsis
This lesson assumes that students have completed Lesson 1 or explored the simulation in other significant ways. In this lesson, students design and perform a quantitative experiment in the Traffic Control simulation. By altering variables for signal timing and traffic speed, student predict and create measurable effects on the traffic system. Students compare those effects to expectations from their hypotheses.

Objectives:
• Students will design and conduct an experiment with quantitative measurements.
• Students will describe how increasing or decreasing a variable affects a solution.

Glossary:
The following terms are used throughout the lesson and demarked with boldface. Consider reviewing these terms as they apply to traffic management with students before beginning the lesson.

Variable - a quantity that can assume any of a set of values.
Offset – the amount of time that a signal light changes slightly off from the rest of the system or a set difference of time from a central clock.
Property - characteristics or attributes of an object, number, or system.

Materials:
For the instructor:
• Computer with projector.

For the students:
• Lesson 4 Handout
• Computer with word processing program and the ability to save.
• Link to Traffic Control simulation: http://street.umn.edu/GAME_traffic.html
Activity 1: Quantitative Experimentation

Note: This activity can be done individually or in small groups.

1. Explain that in this session, students will experiment with variables to determine how they could affect a traffic system. Unlike the previous lessons, this lesson will emphasize quantitative hypotheses and results. The goal is to get increasingly specific and rigorous in experimental design.

2. Review the variables used in the Traffic Control simulation. Ask students to list the other factors or properties they can manipulate in the simulation:
   a. Traffic speed
   b. E-W green
   c. N-S green
   d. Network size
   e. Offset

3. Using the Lesson 4 handout, students should design a quantitative hypothesis using one of the variables. Some examples of quantitative hypotheses might be:
   - In a 3 x 3 fixed-time environment with a N-S and E-W green lights of five seconds, a two-second offset between each E-W intersection will reduce average queue lengths by 20%.
   - In a 3 x 3 fixed-time environment with a N-S and E-W green lights of equal intervals, the offset that will minimize average queue length is 50% of the fixed-time interval.
   - In a 2 x 2 fixed-time environment with a fixed-time interval of eight seconds and zero offset, drivers can expect 250% increase in their delay time between low traffic and high traffic periods.

4. Teachers may wish to check students’ hypotheses before allowing them to proceed with designing the experiment. Once students have written a suitable hypothesis, they should outline in writing the steps necessary to conduct the experiment. Students should pay special attention to which parameters are held constant and which are varied between trials.

5. Students should then use the Traffic Control simulation to conduct their experiment. Graphs will provide quantitative results and should be copied as a screenshot and saved for later use.
6. Conclusions should be quantitative and supported by graphical evidence. Students should include suspected reasons the original hypothesis was confirmed or contradicted, and within what margin of error? The conclusion should also include additional factors that may be relevant, the potential impact of their experiment on traffic management decisions, and suggestions for further investigation.
This activity emphasizes quantitative hypotheses and results. Your goal is to get increasingly specific and rigorous in experimental design and use the Traffic Control simulation and, if necessary, the Traffic Control spreadsheet from Lesson 3 to quantitatively test your hypotheses. All information should be gathered and analyzed in one coherent report.

**Hypothesis: What will you test?**

First, formulate a quantitative hypothesis. What can you measure in the simulation, and how can you determine its impact? Some examples of quantitative hypotheses might be:

- In a 3 x 3 fixed-time environment with a N-S and E-W green lights of five seconds, a two-second offset between each E-W intersection will reduce average queue lengths by 20%.

- In a 3 x 3 fixed-time environment with a N-S and E-W green lights of equal intervals, the offset that will minimize average queue length is 50% of the fixed-time interval.

- In a 2 x 2 fixed-time environment with a fixed-time interval of eight seconds and zero offset, drivers can expect 250% increase in their delay time between low traffic and high traffic periods.

Write your own unique hypothesis here:
Experiment Procedure:

Design an experiment that will effectively test your hypothesis. In creating your experiment, consider such questions as the following:

- Which parameters are held constant and which are changed?
- What steps will you follow to ensure control over your experiment?
- How will you measure the initial and final traffic flow conditions?
- Which “scores” that the simulation tracks will be critical to your experiment?
- What evidence will you look for to prove or disprove your hypothesis?

Create your experimental design here or in a separate document:

Observations & Results

Create a coherent report that includes the hypothesis, experimental procedure, screenshots of any relevant graphs or simulation views, spreadsheet charts and anything else relevant to the experiment. Describe your observations and the numerical results of the experiment.

Conclusion

Conclude your report with your interpretations of the results. Do this in a way that convinces the reader that your conclusions, whatever they are, are justified by the evidence. Refer back to the graphs, screen shots and other objective data as necessary.
Lesson 5 – Traffic Data Analysis

Synopsis
This lesson is best scheduled over the course of two or three instructional periods – the first to provide background information and instruction on how to analyze traffic patterns with the DataPlot application. The second and third session should allow enough time to complete an assignment in which students apply their traffic pattern analysis to recommend when to close an interstate highway lane.

After a brief description of the traffic control technology used in the metro area and throughout the state, students use the MN/DoT’s DataPlot application to examine authentic data from a detector station.

The lesson concludes with students working in small groups to analyze data from a stretch of highway to identify the optimal time to close a lane for a 1-week road maintenance project.

Objectives:
1. Students will identify how traffic counting informs planning.
2. Students will describe why data, to be accurate, must be collected in a uniform manner over a fixed period of time.
3. Students will use traffic flow data to identify peaks.
4. Students will use the DataPlot application to determine relationships between variables.
5. Students will use the DataPlot application to study a section of interstate to determine when might be the optimal time to close a lane for road repairs.

Glossary

Algorithm – a procedure for solving problems, following a logical sequence of steps

Density (vehicles per mile) = Flow (vehicles per hour) / Speed (miles per hour)

Flow is the rate in which vehicles arrive at a particular point on a roadway, described in terms of vehicles per hour.

Headway - the amount of time that elapses between two vehicles passing the same point traveling in the same direction on a given route.

Sample - a small part intended as representative of the whole.

Saturation - The maximum number of vehicles from a lane that can cross through an intersection in one hour.

Speed (miles per hour)
**Throughput** – the volume of vehicle or passengers passing a specific point during a predetermined period of time.

**Traffic volume** - the actual number of vehicles to arrive during a sampling period (e.g. 30 seconds).

**Variable** - a quantity that can assume any of a set of values.

**Materials:**

For the instructor:
- MN/DOT’s “All Detector Report, February 2008” or more recent, if available:
- MN/DOT’s Traffic Data Collection Map for either Greater Minnesota or the Metro Area:
  [http://www.dot.state.mn.us/traffic/data/html/collsites.html](http://www.dot.state.mn.us/traffic/data/html/collsites.html)
  [http://www.dot.state.mn.us/traffic/data/maps/countsites/outstatesites.pdf](http://www.dot.state.mn.us/traffic/data/maps/countsites/outstatesites.pdf)
  [http://www.dot.state.mn.us/traffic/data/maps/countsites/metrosites.pdf](http://www.dot.state.mn.us/traffic/data/maps/countsites/metrosites.pdf)
- MN DOT’s DataPlot application available at
  [http://data.dot.state.mn.us/datatools/DataPlot.jnlp](http://data.dot.state.mn.us/datatools/DataPlot.jnlp)
- computer with projector

For the student:
- handouts 1, 2, and 3 – either as printout or cut and pasted into a standalone word processing document
- computer with ability to print or save files, loaded with:
  - Sun’s Java Runtime Environment
  - word processing software
- access to MN/DOT’s “All Detector Report, February 2008” or more recent if available:

**Preparation**

**DataPlot application preparation**

The MN/DoT maintains a network of thousands of loop detectors across the metro area’s highway system. Data from each detector may be viewed using the Regional Traffic Management Center’s DataPlot application.

Before you begin class, use the link below to download the application. It is recommended that the teacher or technical staff download and check that the application before students use it. Alternatively, you might bookmark this link on each computer or copy the worksheet “DataPlot Application” for each student.

[http://data.dot.state.mn.us/datatools/DataPlot.jnlp](http://data.dot.state.mn.us/datatools/DataPlot.jnlp)
A list of detectors with mapped locations at intersections across the state is available at the link below. All of these detectors can be entered and analyzed in the DataPlot application. [http://www.dot.state.mn.us/tmc/trafficinfo/downloads/adr.pdf]

Test out the DataPlot application. One can enter a single or multiple detectors and then compare several variables for a single date. A second option is to enter in one detector but compare its data across several dates.

Try entering multiple detectors and comparing data across days, months (>), even years (>>).

**IMPORTANT:** Check whether the DataPlot application will run on student machines. Once the application downloads and a detector has been entered, one should be able to click on any of the date buttons and see a graph. If no date buttons are enabled, there could be a proxy server issue.

Check with your system administrator to provide proxy permissions for the application to work. DataPlot is a Java WebStart application and operates under the parameters set in the WebStart preferences. Ask your system administrator to use the command line and enter [javaws –viewer]. This will open the WebStart application viewer. Go to the preferences and setup the proxy information there.

**Activity 1 preparation:**
- Prepare projector to display images.
• Prepare handout 1

**Activity 2 & 3 preparation:**

- To display detector maps, access the MN/DOT ADR report at: [http://www.dot.state.mn.us/tmc/trafficinfo/downloads/adr.pdf](http://www.dot.state.mn.us/tmc/trafficinfo/downloads/adr.pdf)
- Access the DataPlot application from Run DataPlot.
- Prepare handouts 2 and 3.

**Activity 1: Why Do We Collect Data?**

1. Ask students to think about why it may be important to collect data on vehicle volume. What sorts of data would traffic engineers and road designers want to know?
2. Distribute handout 1: “Lesson 5 - Why and How Do We Collect Traffic Data?” and ask students to form small groups of 3 – 4 people each. Allow about 10 – 15 minutes for student groups to complete and discuss the handout.
3. Introduce the variables and ask students to share why these are important to collect:
   - Density – indicates how “thick” the traffic is at that point in time.
   - Headway – indicates the distance between vehicles.
   - Speed – indicates how quickly vehicles can move through that road section.
   - Volume – indicates how many vehicles are on that section of road.
4. Display a picture of an I-94 highway scheme, one of which is included in the teacher presentation Powerpoint. Indicate to students how the various detectors that are designated on the map:
   - a. entrance ramp detectors
   - b. exit ramp detectors
   - c. roadway detectors (note that these are grouped into "stations" of 2 or 4).
5. Review how technology is used to generate traffic counts and vehicle volume:
   a. Prior to the 1990's, most traffic counting was done by human observation in six hour shifts.
   b. Since the 1990's, technology such as traffic counters have dramatically increased the quantity and accuracy of data collection.
   c. MN DOT uses loop detectors connected to fiber optics to continually monitor and collect traffic data. This data enables the Traffic Management Center to identify problem spots and adjust ramp meters to manage the flow of traffic.
Lessons for High School Students
Lesson 5 Handout
Why and How Do We Collect Traffic Data?

How Is Data Collected?

1) Think for a moment why traffic engineers and road designers need to know how a road is used. What kinds of information would be necessary to collect? Share your ideas with your small group.

2) How is this information collected? Read through the following information:

Prior to 1990, the Minnesota Department of Transportation and local governments didn't have many tools to determine traffic volume. Workers had to conduct manual counts by sitting by the road and counting cars for hours on end. Aside from being incredibly boring, manual counts were expensive and limited the amount of data that could be collected. Now, numerous technologies exist that make the task easier, cheaper, and more accurate, and therefore lead to better planning of traffic systems.

The type of traffic counter in the picture to the left is used on minor roads to determine traffic volume, usually over a 48 hour period. Each time tires cross the device, the counter notes another vehicle. These detectors can count traffic in both directions.

Because they are mechanical, they have many advantages. They never get tired or miss vehicles. Many can be deployed at once so larger areas of a city or county can be surveyed.
Each of the boxed areas in the Minnesota map to the left is a vehicle count site. With all of these data collection sites, an incredible amount of data is now available to traffic engineers and road designers that had not been previously available.

You've probably come across a ramp meter like this one at some point. Ramp meters are a tool used to increase freeway volumes, trip reliability, and freeway speeds, while decreasing travel time and crashes. A complex **algorithm** continually adjusts the signal timing based on current traffic conditions.

Where does the data for this complex algorithm come from? To continually adjust to traffic conditions, it must have a continuous stream of information...
Similarly, have you noticed the signs on the highways that tell you how long it’s going to take you to get to a certain intersection? Ever wonder how the system “knows” how long the travel time will be to get from one point to another at any given time of the day?

The answer to these questions literally lies in the roadway. These devices, called "loop detectors", are one or more loops of wire embedded in the pavement.

Each loop generates a magnetic field that is reduced when a vehicle passes over it. The reduction of magnetic field is detected electrically and sent to a controller box. This box relays the vehicle’s presence over a fiber optic link back to the traffic management center (the RTMC). All this takes place in less than a second and supplies the algorithm with a continual stream of data needed to update the system.

Discussion Questions:

Think of all that data that is generated each year. How might all this data help in designing roads? How might this data collection affect your daily life?

What does this emphasis on data collection and analysis tell you about the kinds of careers that can be found with a traffic management center? List some of the jobs you would expect to find at such a center.
**What Data Is Collected?**

In the next few activities, you’ll come to better understand the types of data that are collected by the system and use this knowledge to analyze traffic patterns. You will use data from an authentic situation to plan when to close down a lane for road repairs.

Look over these definitions. Discuss each term with your group and write down three reasons why these data would be important for a traffic engineer or road designer to know. How would they inform about how a road is used?

**Density** (vehicles per mile) = Flow (vehicles per hour) / Speed (miles per hour)

**Flow** - the rate in which vehicles arrive at a particular point on a roadway, described in terms of vehicles per hour.

**Headway** - the amount of time that elapses between two vehicles passing the same point traveling in the same direction on a given route.

**Saturation** - The maximum number of vehicles from a lane that can cross through an intersection in one hour.

**Traffic volume** - the actual number of vehicles to arrive during a sampling period (e.g. 30 seconds).
Activity 2: Discovering Traffic Patterns

1. Explain that for the next activity, students will use a graphing application called DataPlot to analyze data generated by these detectors and determine patterns of road use. The application is available free from the link below and should be set up and tested on student machines prior to class.

[ http://data.dot.state.mn.us/datatools/DataPlot.jnlp]

A typical screen from this program is below, and you may wish to show this to the students before beginning the activity to get their interest.

2. Display "Roadway Diagram 1" (I-94 & Manning Ave. Interchange) taken from the MN DOT "All Detector Report - February 2008" as an example of a detector map.
3. Note to students that the number of roadway detectors indicate how many lanes of traffic there are (3) – that there is one detector for each lane of traffic.

4. Direct students to launch the DataPlot program.

Note, when they [http://data.dot.state.mn.us/datatools/DataPlot.jnlp](http://data.dot.state.mn.us/datatools/DataPlot.jnlp) run DataPlot, students should click "TRUST" to allow the program to run: [Run DataPlot]

5. Direct students to enter in the detector for the first westbound lane (5101) by simply typing in "5101" in the "Enter detector(s):" field.
6. Demonstrate how to set variables for the two axes. Remind students to be sure they have "time" selected for the x-axis and "flow" selected for the y-axis.

7. Explain that for the rest of the activity, students will investigate several variables for an intersection.

8. Distribute handout 2: “Lesson 5 – Discovering Traffic Patterns”. Direct students to use the handout to help guide them through how to analyze an intersection.

9. After about 20 – 25 minutes, call students back to the larger group. Ask a few to use the projector to demonstrate the traffic patterns they found.
Assignment: In this activity, you will use the DataPlot application to investigate, compare, and describe traffic flow patterns at one highway intersection over several days of a week. Be sure to write down your observations and answers to questions.

1. Remember that the term "flow" signifies the number of vehicles crossing the detector.
3. Identify a detector you think would be interesting to study and enter that detector number into DataPlot.
4. Start with a guess regarding what might be a high volume day of the week and low volume day of the week for that particular detector. Click on those two days in the same week.
5. Compare the graphs. What do you notice? Does the flow rate change? How much? How does it vary of the course of the day?
6. Select each day of the workweek for that detector.
7. Is there a consistent pattern through the week? Why would traffic flow follow this pattern?
8. Select a week from another year.
9. Compare the traffic flow for that week with the traffic flow from a different year. Did the pattern remain largely the same or did it change? Why might that be?
10. The DataPlot application also allows you to select either multiple dates for one detector or multiple detectors for one date. We'll use this feature to compare data collected on the same day from three different detectors.

- First, clear any detectors that are currently graphed.
- Choose an intersection and a direction (westbound, eastbound, northbound or southbound) with at least three detectors. Enter the codes for all three detectors for the lanes into DataPlot. Each detector will be graphed in its own color.
- Then click on a weekday, non-holiday date to generate a graph. Set the smoothing to 60 minutes.
- Review the graph – what does the graph reveal about the traffic flow for that point in time? Again, compare with the same week in previous years. Has traffic flow changed or remained consistent across years? How do you know?
Activity 3: Road Repairs

1. Explain the final activity – students will use their understanding of traffic patterns and variables to decide when to close a lane for a major repair.

2. Review the variables flow, headway, speed, and density.

3. Display "Roadway Diagram 2" (I-94 & Lexington Ave. Interchange) taken from the MN DOT document "All Detector Report - February 2008". Depending on the ability of the group of students, the teacher may wish to have each student group identify their own particular intersection to study.

4. Explain that students will work together in a small group to determine when a lane should be closed for a week-long road repair.

5. Point out that students will have to investigate data from several road detectors over the span a few years to determine the best time of year to close the road.

6. Distribute handout 3: “Lesson 5 - Road Repairs” and then divide the class into teams.

7. Review how to take and paste screenshots into a word processing document.

8. Provide students with ample time to complete the assignment. It may take an additional class period or time outside of class to do so.

9. If time allows, have students present their findings to the class. One effective way of doing this is as a role-play scenario. Have each team act as a team of engineers presenting their plan to a city council (a panel of students). The city council needs to be convinced that the project is carefully planned to allow a minimum of disruption. Council members should ask questions of the engineers and expect answers to be based on authentic data and clear reasoning.
**Assignment:** In this final activity, use your understanding of traffic patterns and variables to decide when to close a lane for a major repair. Be sure to review the traffic patterns across several months and years before you decide. Then, prepare a written report explaining why your chosen week is the best time to close the lane.

**Step 1: Variable Review**

Work together with your group to review each variable means.

- **Density** (vehicles per mile) = Flow (vehicles per hour) / Speed (miles per hour)

- **Flow** - the rate in which vehicles arrive at a particular point on a roadway, described in terms of vehicles per hour.

- **Headway** - the amount of time that elapses between two vehicles passing the same point traveling in the same direction.

- **Volume** - the actual number of vehicles to arrive during a sampling period (e.g. 30 seconds).
Step 2: Research Traffic Patterns

A station contains four detectors. For instance, station 548 contains detectors 2663, 2664, 2665, and 2666.

You assignment is to determine when a left lane could be closed for resurfacing, which will take a few days. The work needs to be scheduled for the warmer months, typically between April 15 and September 15.

Working with your group, analyze the data from the detectors to determine when the best time would be to close the left westbound lane at a station. You should make a recommendation for any 1-week period between April 15th and September 15th. To be sure you've analyzed a sufficient amount of data, your period of study should encompass a two-year period, sampling the same week for each month. You should have 18 data points to analyze.

To complete the assignment, prepare a written report, complete with screenshots of graphs, describing the traffic pattern for your chosen station and your group’s recommendation for closing the lane. The recommendation should refer back to your group’s analysis of the lane and state why your chosen week is the best time to close the lane.
Addendum 1 – Funnel Traffic Lesson for Upper Elementary and Middle School Students

Lesson: Funnel Traffic
Following a demonstration on traffic volume (using a funnel and several marbles), students graph the data generated for traffic time and vehicle volume.

Objective:
1. Students will identify how traffic flow can become constrained.

Materials:
For the instructor:
- 59 marbles of one color, 1 marble of a contrasting color (e.g., 59 white, 1 black).
- stopwatch
- long-stem funnel with a 12 to 20 mm opening

For the student:
- writing paper and pen/pencil
- graph paper and pencils

Preparation:
- Divide 59 marbles into groups of 5, keeping the contrasting marble separate.
- Distribute graph paper and pencils
- Set stopwatch to zero
- Draw a 2 column chart on the board: # of marbles | time

Procedure
1. Pose question: How do engineers know when to put in a signal or change its timing? How do engineers know whether traffic volume is below saturation?
2. Display funnel, 5 marbles - 4 of one color and the contrasting color (e.g., black).
3. State that we’re going to do a little experiment about traffic volume and travel time. Ask students to imagine that the funnel is a roadway and the marbles represent vehicles.
4. Ask a student to take the stopwatch and predict how long it will take the five marbles to travel through the funnel.
5. Cover the bottom of the funnel and put the 5 marbles inside.
6. Start the stopwatch at the same time you uncover the bottom of the funnel. Time how long it takes the black marble to come out of the funnel.

7. Record the time on a 2-column chart: # of marbles | Time out of funnel

8. Repeat the process a few times, adding 5 marbles each time.

9. Ask students to graph the results, with graph paper, plotting the number of marbles vs. the time for the black marble to drop out of the funnel.

10. Discuss the results - why did the black marble take longer each time to make it through the funnel?

11. Relate exercise to traffic. Ask students to consider the scenario if the marbles were cars and the funnel was a traffic light. Write the words "traffic volume" on the board and explain that traffic volume means the amount of cars (or marbles) moving through a system (in this case - the funnel).

12. Point out that in an intersection, just as with this funnel, the amount of time it takes a car to move through an intersection is dependent on the traffic volume - the greater the traffic volume, the greater the time it takes to move through an intersection.
Addendum 2 – Problems in Traffic - Small Group and Independent Study

Synopsis
The following three problems cover different potential career areas related to traffic management. They are designed to present students with situations that would require skills developed in a certain course of study (for example, psychology, automotive design, or traffic engineering).

Objectives:
• Students will understand engineering as societal problem solving.
• Students will develop beginning skills in system analysis.
• Students will identify factors outside of engineer's control that affect system (driver distraction, volume, speed).
• Students will identify causes of congestion and effects of congestion (economic, environmental, etc.).
• Students will compare and describe how decisions balance cost with outcome.

Three Problems:

1) Incident Related Congestion – 35 W Bridge Collapse

Using sensor data from August 1, 2007 and the DataPlot application, students compare effect of collapse on system a month before and after the event. Given that each lane can handle a fixed amount of traffic, what solutions would students suggest? Using MPR and MNDOT websites, students research the solutions and evaluate their effectiveness by compare sensor data from September, December 2006 and 2007 and March 2007 and 2008.

2) Driver distraction: Cell phones and iPod Use Among Young Drivers

Students research young driver accident rates and then review two studies (Driving Performance While Engaged in MP-3 Player Interaction and The Effects of Cell Phone Conversation Difficulty on Driving Performance) to conjecture how iPod and cell phone use could affect young drivers.

The studies are available online at:

MP3 study:
Cell phone study:


After deciding on the key factors and findings from the studies, students fashion a mock-up car cockpit to try to develop and test new habits for using these device and compare those new habits with complete abstinence. Students present their findings in a public awareness campaign.

3) Metro-area traffic growth: Solutions Besides Cars?
Students analyze data for the past 5 years using the DataPlot application to try to project future traffic growth for a busy interchange. Students then break into smaller groups to use vetted information sources to research tolling options, car pooling, building extra lanes as well as comparing bussing vs. train to determine the most cost effective method for reducing the traffic congestion,