MODULE 6: CONGESTION PRICING AND FLOWCHARTING

LESSON 1: CONGESTION PRICING

GRADE LEVEL: 9 - 12

Congestion-based tolling is an aspect of intelligent transportation systems that is being implemented frequently on highly-congested road networks in the US and around the world. It is a topic that also lends itself to beginning-level programming, based on its iterative nature. Through discussion, analysis, and a hands-on programming activity, students will be able to understand the benefits of congestion-based toll pricing and at the same time, be provided with a foundation for flowcharting and programming.

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Lesson 1: Congestion Pricing

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Grade Level: 9-12	**Lesson in this Unit:** 1 of 1
Time Required: 120 minutes	**Lesson Dependency:** None
Keywords: transportation engineering; intelligent transportation systems; congestion-based pricing, flowcharting	

Related Curriculum

Subject Areas	Science; technology; engineering; mathematics
Curricular Units	Intelligent transportation systems
Activities	cooperative learning, simple flowchart, congestion pricing flowchart

Educational Standards

This lesson plan and its associated activities are correlated to the national standards in the each of the core discipline areas of STEM: Next Generation Science Standards, American Association for the Advancement of Science Standards, Standards for Technological Literacy, International Society for Technology in Education Standards, Common Core Mathematics Standards, and the National Council of Teachers of Mathematics Standards.

Materials List

Flowcharting worksheet, app development software

Pre-Requisite Knowledge

None.

Learning Objectives

- Students will learn about congestion-based pricing: its purpose and various possible methodologies.
- Through discussion, students will learn flowcharting concepts: the methodology, the meaning of symbols, and the purpose of flowcharting.
- Students will learn to create flowcharts for a simple task and then to demonstrate an example congestion-pricing algorithm.

Introduction/Motivation

Congestion-based tolling is an aspect of intelligent transportation systems that is being implemented frequently on highly-congested road networks in the US and around the world. It is a topic that also lends itself to beginning-level programming, based on its iterative nature. Through discussion, analysis, and a hands-on programming activity, students will be able to understand the benefits of congestion-based toll pricing and at the same time, be provided with a foundation for flowcharting and programming.

Lesson Background & Concepts for Teachers

- **Activity 1 – Discussion of Congestion-Based Pricing**

How Congestion Pricing Works
Congestion pricing is the practice of instituting a toll on a highly-congested roadway in order to dissuade drivers from using the roadway. Typically the cost of the toll is varied based on the amount of congestion on the roadway. In theory, toll prices are increased until enough drivers are deterred from using the roadway that the congestion is alleviated.

Congestion-based toll prices can be set at a fixed price for the entire day or can vary throughout the day based on fluctuating congestion volumes. A fixed price tolling structure will typically be used in city centers which contain congestion at all times of the day. These tolls discourage driving in city centers and encourage other forms of transportation such as public transit, bicycling, or walking.

A variable priced tolling structure is typically used on highways leading into and out of major cities. Tolls are priced higher during times of the day when it is known that the roads are congested (referred to as “peak hours”), and lower during the other times of the day when it is known that the roads are less congested (referred to as “off-peak hours”). This allows drivers to choose which is more important to them: avoiding the higher tolls or traveling during peak hour travel times. When drivers choose to avoid the higher tolls, there is less congestion on the roads during peak hours, resulting in a smoother, less-stressful, and more fuel-efficient drive for everyone.

What Problems Does Traffic Congestion Cause?

Traffic congestion leads to prolonged travel times, which results in wasted fuel and wasted time commuting. The wasted fuel has important environmental implications as well as financial implications for the drivers themselves. The wasted time leads to many different negative indirect but measurable effects: extensive research has linked an increase in time per day spent commuting to a decrease in overall health.

In congested conditions, vehicles use more fuel than in optimal driving conditions, because increased traffic congestion results in slowdowns, delays, and eventually prolongation of commute times. Conventional cars' engines are left running even when highway congestion causes traffic to slow down to stop-and-go speeds. This is bad for the environment: more carbon dioxide is released into the atmosphere than would be released during smoother, more typical traffic flow conditions. Hybrid-electric or fully electric cars would reduce this problem, but would have no effect on the long, inefficient commutes caused by congestion. Studies have shown that increased commute times cause drivers to suffer from decreased physical and mental health. The most optimal solution to the congestion problem is to eliminate it altogether. Thoughtful implementation of congestion-based tolling systems is one way to reduce congestion.

The Benefits of Congestion Pricing

By varying the price of tolls, authorities can offer financial incentives that help influence driver behavior and promote sustainable travel practices. For example, tolls can be varied throughout the day to encourage travelers to adjust their schedules in order to travel during off-peak hours, when prices are lower. For some drivers, driving during off-peak hours may not be possible. Even so, it is likely that significant differences in toll prices between hours could be the deciding factor that convinces a number of other drivers to avoid peak travel hours. This causes at least a fraction of the drivers that once used the roads during peak hours to use the roads at off-peak hours, leaving the roads less congested during the times of the day when they are typically most busy. The Federal Highway Administration says that "the majority of rush hour drivers on a typical urban highway are not commuters." These drivers likely have more flexibility in their schedules, making it easier for them to find an alternate travel time or route, in order to avoid paying higher toll prices on urban highways during the times of the day when commuters are typically present.

Implementation Strategies

There are many different methods of implementing congestion pricing on roadways. Some methods implement tolls on only one or two lanes of a highway while others toll the entire road. Some methods utilize a pricing structure that varies based on congestion levels while others use a flat rate fee in order to deter drivers. The following are currently used congestion pricing implementation strategies.

1. **Variably Priced Tolls**

Variable congestion pricing is typically used on highways leading into and out of major cities. These highways experience congestion at peak times of day. Congestion tolls are implemented on the roadway in order to encourage drivers to travel during off peak times.

Most variable congestion pricing in the United States uses variably-priced lanes, often called High Occupancy Toll (HOT) lanes or Express lanes. These lanes parallel (or are adjacent to) non-tolled general purpose lanes. When congestion is high during peak hours, the fee to drive in these lanes is expensive. When congestion is low, the fee to drive in these lanes is cheap. During peak times, drivers can choose to pay the toll and drive faster in the variably-priced toll lanes or not pay the toll and drive slower in the congested general purpose lanes. This implementation strategy mainly reduces congestion in the tolled lanes.

Additionally, variable congestion pricing can be implemented on the entire roadway (not just one or two lanes). This implementation strategy seeks to reduce congestion on the entire roadway. In this scenario, drivers must either choose to pay an expensive toll during peak times, wait for an off peak time to travel and pay a cheaper toll, or find an alternate toll-free route to their destination.

Many congestion priced lanes and roadways reduce or waive the toll if the vehicle contains multiple passengers. Personal vehicles with several passengers, public transit buses, and emergency vehicles are charged either no toll or a lower price toll than single occupancy vehicles (vehicles with no passengers). This strategy reduces congestion by encouraging carpooling and deterring single occupant vehicles from using the roadway.

Tolls for both types of congestion pricing systems are usually collected using electronic tolling systems. This method uses an overhead reader to scan an electronic device kept in or on the car itself, allowing a toll to be paid completely electronically. Some congestion pricing systems require that all cars have an electronic device while other systems allow the driver to pay at a toll-booth at the start of the toll road. The picture to the right is a real-world example of variably priced lanes. Variable pricing on an entire roadway (all lanes) would be similar to this example except all lanes on the highway would be tolled.

Example of Variably Priced Lanes:

The I-495 HOT lanes (located in Virginia around the District of Columbia) are a great example of variably priced toll lanes. This system is a set of 2 tolled lanes (on the left) and 3 non-tolled lanes (on the right). Drivers that wish to bypass the congestion in the non-tolled lanes can pay a fee to use the relatively empty HOT lanes. This fee changes throughout the day based on the amount of congestion. During highly-congested times, the toll to use the HOT lanes is expensive. This ensures less drivers use the HOT lanes, keeping the lanes relatively empty for those willing to pay.

Collected tolls are not only based on the time you travel but on the distance. The longer one travels in the HOT lanes, the higher the toll fee. This picture displays a sign that informs the driver of the prices he/she will pay to use the toll road to reach their exit. Farther away exits cost more money to reach. The numbers seen on the sign will also increase or decrease based on the current congestion level of the roadway.

2. **Fixed Area Wide Pricing**

Fixed area wide congestion pricing is typically used in city centers. Driving on any of the roadway segments within the area of the city center cost a fixed fee. These central areas experience congestion at all times of day, so the toll price usually remains fixed throughout the day. Congestion tolls are implemented in these central areas in order to discourage driving and encourage public transit usage and walking.

This congestion pricing systems works by tolling any vehicle that crosses an imaginary line (or Condor line) into the toll area. Tolls are collected using either cameras or scanners. Similar to variably priced toll collection, some systems use an overhead reader to scan an electronic device kept in or on the car itself. Other systems use cameras to read the license plate number on a car entering the area, match it against a database, and send the toll bill to the owner of the license plate.

Example of Fixed Area Wide Pricing:

An example of fixed area wide pricing is London's congestion pricing system. If a driver enters the area shaded in red, a network of cameras will read and record the vehicle's license plate number as the vehicle enters, drives around, and exits the area. Each time the car enters the area, the vehicle owner will be billed about $17. By charging for access to roads within city centers, drivers that are able to reroute their travel to avoid the city center will do so. Others will choose to use public transit to enter the city center. These changes in behavior decrease the level of congestion on busy city roads.

- **Activity 2 – Discussion of Basic Flowcharting Rules/Procedures**

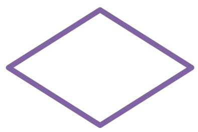
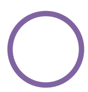
Flowcharting is a practice used in computer programming. In the same way a writer may construct a visual storyboard before writing out the entire story, a programmer uses a flowchart to organize their ideas into steps that are visually appealing and easy to follow. A flowchart is a visual demonstration of the concepts behind an algorithm. An algorithm is just a detailed sequence of actions or steps required to achieve a given task. In essence, a flowchart graphically shows the steps of an algorithm or process.

Flowcharts consist of symbols connected by arrows that follow a path from the starting symbol to the ending symbol. In basic flowcharts, the arrows flow in just one direction, usually from one symbol to the next. The most common flowcharting symbols/shapes are shown in

Table 1. Each symbol:

1. is connected to other symbols using arrows.
2. represents a single step within a process (the process is the entire flowchart).
3. is labeled with the name of the step and any other information used within that step.
4. has a specific shape that corresponds to the type of step that is taken.

Table 1: Common Flowcharting Symbols

Name	Symbol	Use/Indication
Terminator		Used to show the starting and stopping point of the process.
Process		Displays an action (or operation). This can also be used for calculation, defining a variable, or updating a variable.
Decision		Indicates a point in the process where a choice/decision has to be made. This choice/decision is usually Yes/No or True/False. Text inside the symbol describes the choice, and then arrows flowing out of the sides are labeled based on the outcome. (Usually these arrows extend out from the right and bottom).
Data		Indicates any type of data input/output to and from a process. Example: get X from the user, or print Y. (An example of this shape used in a flowchart can be seen within the flowcharts of Appendix A.)
Connector/ Node		Connectors are used to join two or more arrow lines together. Also known as a node or connecting node.

In order to generate a flowchart that can be used to describe a process, the steps of the process must be written down or organized in some way. Then, the types of steps must be determined, such as whether each step is a decision, an input/output of data, a process, etc.

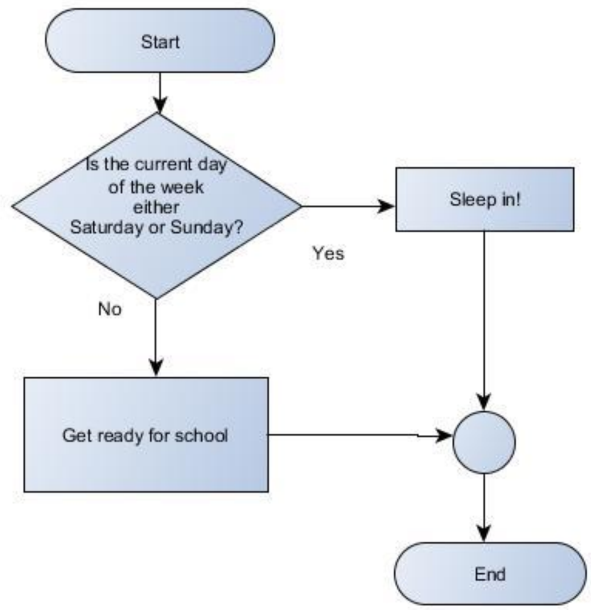
Flowcharting has its own set of rules in order to standardize the practice of flowcharting, which are generally consistent across disciplines. A flowchart's basic rules are:

1. The flowchart must start and end with a terminator symbol which is typically labeled "Start" and "Stop".
2. Arrows within the flowchart should not bend or curve. They should only be straight lines to keep everything neat, consistent, and easy to follow.
3. Process and data symbols should have one arrow coming in and one arrow going out.
4. Connector symbols should have two or more arrows that flow in, and only one arrow flowing out.

5. Decision symbols will have multiple arrows coming out from the symbol (usually two: one for “true/yes” and one for “false/no”), each representing a possible outcome of the logical test.

A decision symbol is much like a fork in a road: the path splits into two, a decision must be made, and only one of the two paths is chosen. The general rule for decision symbols is that the “true” or “yes” arrow should come off of the right side of the symbol, and the “false” or “no” arrow should come out from the bottom of the symbol. This is not a standard rule across the industries and disciplines, but it is good practice. At the very least, the best practice is to keep the direction of the “true” and “false” arrows consistent during flowcharting in order to make the flowchart as easy to follow as possible.

For example, in a flowchart that shows the steps for getting ready in the morning, one step might question the day of the week. If it is the weekend, the flow chart may indicate that the person can sleep in. This is considered to be a logical test (“Is the current day of the week Saturday or Sunday? If true, sleep in; if false, get ready for school”). In this case, the flowchart maker would write this step within a decision symbol, since a decision or test needs to be completed. The description of the logical test is then written inside the decision symbol, as shown to the right.

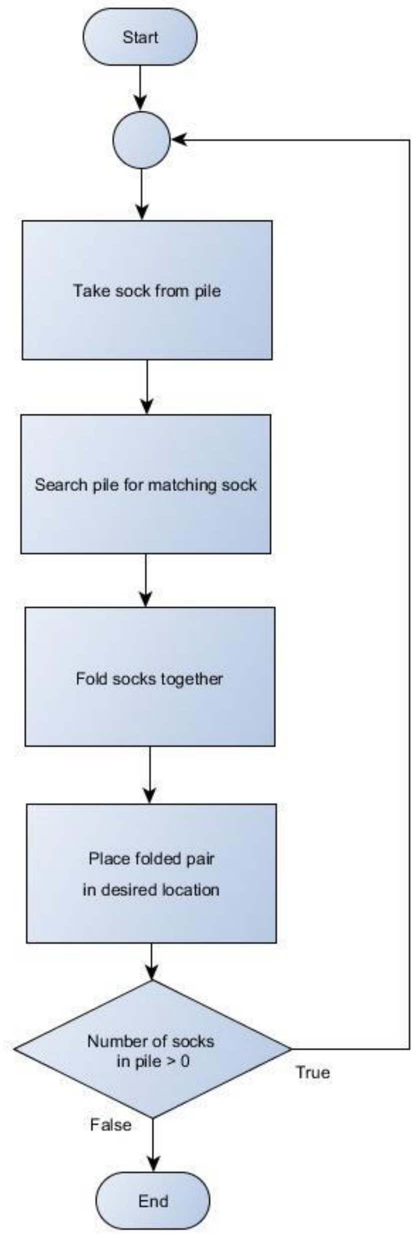


- **Activity 3 – Creation of a Looping Flowchart**

Flowcharts are best suited and most-often used to visually describe the steps of repetitive processes. Repetitive processes are exactly as one would expect based on their name: they occur more than once, usually doing something again and again until certain conditions have been met. Repetition, or looping, is a fundamental concept in flowcharting and programming. An example of a repetitive process would be folding laundry. The simplest example would be folding a number of the same type of clothing, like dress socks, for example. Assuming an individual is folding many (say, 20) pairs of socks, and each pair is unique (each sock only matches with one other sock), the process would look like this:

1. Take a sock from the pile (at random),
2. Find the matching sock (to complete the pair),
3. Fold them together,
4. Put them in the sock drawer (the designated location).

At this point, only one of the 20 pairs have been matched, folded, and put away, so there are still 19 more pairs that need to receive identical treatment. This is where the looping concept comes into play. The “loop” would follow a logical decision (diamond symbol) that occurs at the end of this process: are there still more socks to fold? This logical decision can be thought of as step 5 in the sock-folding process. If there are still more socks to fold, we need to “loop” back to step 1 and begin the process again. If not, that means that all the socks have been folded, so we don’t need to loop back to the beginning and can end the sock-folding process. The flowchart for this process should look something like the one shown.



Flowcharting helps students learn to plan intelligently. It breaks down complex problems into smaller, more manageable ones, applicable in both computer science as well as in life. It is an effective strategy beneficial for students interested in any number of fields, from engineering to creative writing to conflict resolution.

- **Activity 4 – Creation of a Congestion-Based Pricing Flowchart**

Bringing each activity together, a flowchart describing the process of the congestion-based tolling is a natural connection between the two topics. The first section goes through a “stacked-if” flowchart (Appendix A) and the second section goes through a “nested-if” flowchart (Appendix B).

The “Stacked-if” Flowchart (shown in Appendix A)
The name of this flowchart comes from the computer science field, where flowcharting is frequently used. “Stacked-if” decision structures are so named because their logical decisions are sequential and essentially stacked one on top of another. This type of flow chart guarantees that each logical decision is tested every time the algorithm is run.

Starting at the terminator shape labeled “start,” we follow the arrows to a process symbol. In it, each variable is pre-defined. This is common practice in flowcharting: often, the main goal of the flowchart is to set variables to certain values based on the conditions that are present.

The next symbol is a data input/output symbol asking us, the user, for the current time of day. Suppose the time of day is 1:00pm. This is during the Afternoon time period, so we know that the Time of Day is equal to Afternoon.

Our current position in the flowchart is the first decision symbol. This tests if Time of Day is equal to Early Morning. We know this is false, so we would choose to follow the false arrow downward to the next symbol.

The next symbol is another logical test, asking if Time of Day is equal to Morning Peak Hours. Again, we know this is false, so we follow the false arrow downward to the next decision symbol.

This third decision symbol tests if Time of Day is equal to Afternoon. This is true, so this time we follow the true arrow to the process box on the right. This process box updates the toll price to the correct amount for Afternoon, $0.75.

Next, we follow the arrow below that connects to the connector symbol, and follow that arrow down to the final decision symbol. This last decision symbol tests if Time of Day is equal to Late Evening. Similar to what we’ve seen before, we know this is false, and so we follow the arrow down to the second to last symbol: the data input/output box, which tells the user what the toll price should be, based on what it was last set to in the previous steps of the flowchart.

Finally, we follow the last arrow to the “Stop” terminator. A loop can be added to this flowchart (shown in the second image of Appendix A) in order to force the process to repeat and update the correct toll price throughout the day.

The “Nested-if” Flowchart (shown in Appendix B)

The name of this flowchart also comes from the field of computer science. “Nested-if” decision structures are, unlike “stacked-if” structures, “nested” within one another, so decisions can be made faster. The logical decisions are still sequential, but it eliminates the need to test each and every decision once a true value is found.

The nested-if flow chart begins with the same process as the stacked-if flowchart.

Starting at the terminator shape labeled “start,” we follow the arrows to a process symbol which sets the variables as described in the stacked-if flowchart.

The next symbol is a data input/output symbol asking the user for the current time of day; again, exactly the same as in the stacked-if flowchart. We will assume that it is currently operating during the Afternoon time period.

We move on to the next symbol, which is the first decision symbol of the nested flowchart. This is the same as the first decision symbol in the stacked-if flowchart - it tests if Time of Day is equal to Early Morning. Since we are operating during Afternoon, the answer is false, so we follow the false arrow down to the next symbol.

The next symbol is another logical test (a decision symbol). Again, this tests if Time of Day is equal to Morning Peak Hours. We know this is false, so we can follow the false arrow downward to the next decision symbol.

This third decision symbol tests if Time of Day is equal to Afternoon. This is true, so we follow the arrow to the final output symbol, where the toll price is told back to the user.

Finally, we follow the last arrow to the "Stop" terminator. Again, this process can be repeated infinitely to set the correct congestion based toll price every time.

Difference Between "Stacked-if" and "Nested-if"

There is one key difference between the two types of flowcharts that were presented in this lesson plan. When following through the "stacked-if" flowchart, the algorithm must process every question regardless of whether the answer has already been established. In the "nested-if" flowchart, once we establish the time of day, the algorithm ends and does not continue to process additional time of day questions. In the example congestion pricing algorithms there are five mutually exclusive conditions for what the time of day can be. This means that if one is true, none of the others can be true (if the time of day is Early Morning, it cannot be Late Evening at the same time). As a result, it is unnecessary to test each condition every time the way the "stacked-if" flowchart does. While both flow charts are able to accurately assign the toll price, the "nested-if" flowchart is much more efficient compared to the "stacked-if" flowchart.

Another detail to note is that there is no Evening Peak Hours decision symbol in either flowchart. This goes back to the idea of variable initialization. In both flowcharts, we have initially set the Toll Price per Car variable to the Evening Peak Hours rate of $4.99 in the very beginning, before any logical tests have been completed. This is done as a way to save time and computing power: if the toll price (Toll Price per Car) is initialized to $4.99, then during 4 - 6:59 pm (Evening Peak Hours), the flowchart will test each case and find them all to be false, leaving the Toll Price per Car at the correct value for that time of day of $4.99. The time of day in this case is determined to be Evening Peak Hours by the process of elimination, and the toll price would not need to be changed from its initial value. This saves computing power during these busy hours.

Vocabulary/Definitions

Vocabulary Word	Definition
Congestion-Based Tolling	A method used by toll booths to reduce traffic on busy highways by charging an extra fee to road users during peak hours.
Decision Structure	The way decisions are made in flowcharting. This includes (but is not limited to) stacked-if structures and nested-if structures. These present themselves when there is more than one logical decision that needs to be completed during within a single flowchart.
HOT lanes	"High Occupancy Tolling" lanes. This describes the concept of charging a higher toll for low occupancy vehicles than for high occupancy vehicles.
HOV lanes	"High Occupancy Vehicle" lanes. It describes a vehicle that has a certain number of passengers (the exact number varies by location). HOV designations were created by transit authorities in order to encourage carpooling.
Logical Decision	A test that checks whether the given conditions are true based on known information and/or conditions. Examples: "Is the light green?" "Did I roll a 7 or higher?" and "Is the user's password inputted correctly?"
Loop	A loop is a flowcharting tool used to carry out a repetitive task. Usually, near the end of the flowchart, a logical decision will be carried out, and two arrows will branch out: one leads back to the beginning (or wherever appropriate) and one leads to the next section, or the end (again, wherever appropriate, depending on the layout and content of the flowchart).
Nested-if Structure	A series of logical decisions are "nested" within one another, making it so the required logical tests are performed, skipping tests that can be skipped. "Start > Is A true/false? (If true, End) > Is B true/false? (If true, End) > Is C true/false? (If true, End) > End" This cannot be applied to every process, but is useful when the logical tests (A, B, and C) can be skipped based on a preceding logical test. This would happen if the logical test for B could be answered by a certain outcome of logical test for A. (Stated another way: nested-if structures are useful when the logical tests *are* mutually exclusive).
Peak Hours	Times of the day that traffic is highest ("peak" meaning "highest"). The roads need to be able to support the level of traffic that occurs at peak hours. Peak hours may be defined differently, depending on location. Around a major city, peak hours are typically defined as being both in the morning (around 7-10 am) when many commute to work, and the afternoon (around 3-7 pm) when many return home from work.
Process	A task made up of a set of steps. The process is the task that a flowchart is used to visualize.
Repetition	The concept used in flowcharting that requires a task to be completed a number of times in order to complete the given process
Stacked-if Structure	A series of logical decisions is "stacked" on top of one another, making it so each logical decision is tested during the course of the decision structure. "Start> Is A true/false? Is B true/false? Is C true/false? > End." This structure is useful if more than one of the separate logical tests (A, B, and C) can be true at a time. (Stated another way: stacked-if structures are useful if the logical tests are not mutually exclusive).

Associated Activities

- **Activity 1 – Discussion of Congestion-Based Pricing**
  - What is congestion-based pricing and why is it used?
    Congestion-based pricing is the practice of changing toll prices in an attempt to alleviate traffic congestion. This is used often on roads with heavy traffic during busy times (peak hours).
  - What are the different types of congestion-based pricing? Why are they many different types?
    Variably Priced Lanes, Variable Tolling on entire roadways, cordon charges, and area-wide charges. These different methods of congestion-based pricing exist to satisfy different requirements set by different areas. In the case of congestion pricing, "one size" does not "fit all." Many of these strategies can be combined together to improve effectiveness.
- **Activity 2 – Basic Flowcharting Rules/Procedures Worksheet**
  - Students will break into group and complete their own common flowcharting shapes table. The definitions will be given, and the students have to place the shapes in the corresponding boxes.
- **Activity 3 – Creation of a Simple Flowchart**
  - As a class, or keeping the same groups that were formed in Activity 2, students should brainstorm different processes that they can demonstrate using a simple flowchart. These should be repetitive and should require some sort of logical test, as those are the sorts of processes that flowcharts are especially helpful in describing. Examples include the process of folding laundry; the process of setting a table; the process of golfing; the process of wrapping gifts, etc.
- **Activity 4 – Creation of a Congestion-Based Pricing Flowchart**
  - As a class, or keeping the same groups as Activities 2 and 3, student should work together to create a flowchart for any of the 4 types of Congestion Based Pricing.
  - High school students should use looping concepts so that the flowchart runs multiple times.

Lesson Closure

The students should come back together as a class and discuss the various flowcharts they've created for Activity 4's Congestion-Based Pricing Flowchart. Discuss whether the different groups' flowcharts utilized a nested-if decision structure or a stacked-if decision structure for their chart. Ask the students the pros and cons of both types of decision structures, why they made their chart the way they did, and which type of decision structure they prefer. There is typically not just one right answer, but conversely, there are some ways that are more efficient than others (for Activity 4, the nested-if structure is the most efficient method). Talk about the different types of congestion-based pricing and discuss how flowcharts that describe the different types would have some similarities but also some differences.

Transition this discussion into one about the benefits of flowcharting. Have students recall that flowcharts were developed and are mainly used in the computer-programming field as the first step of writing code/programs. However, flowcharting can be a valuable tool in many fields. Students might have ideas for other places flowcharts could be used in the real world.

Attachments

- Symbols in Flowcharting Worksheet

Extensions/Multimedia

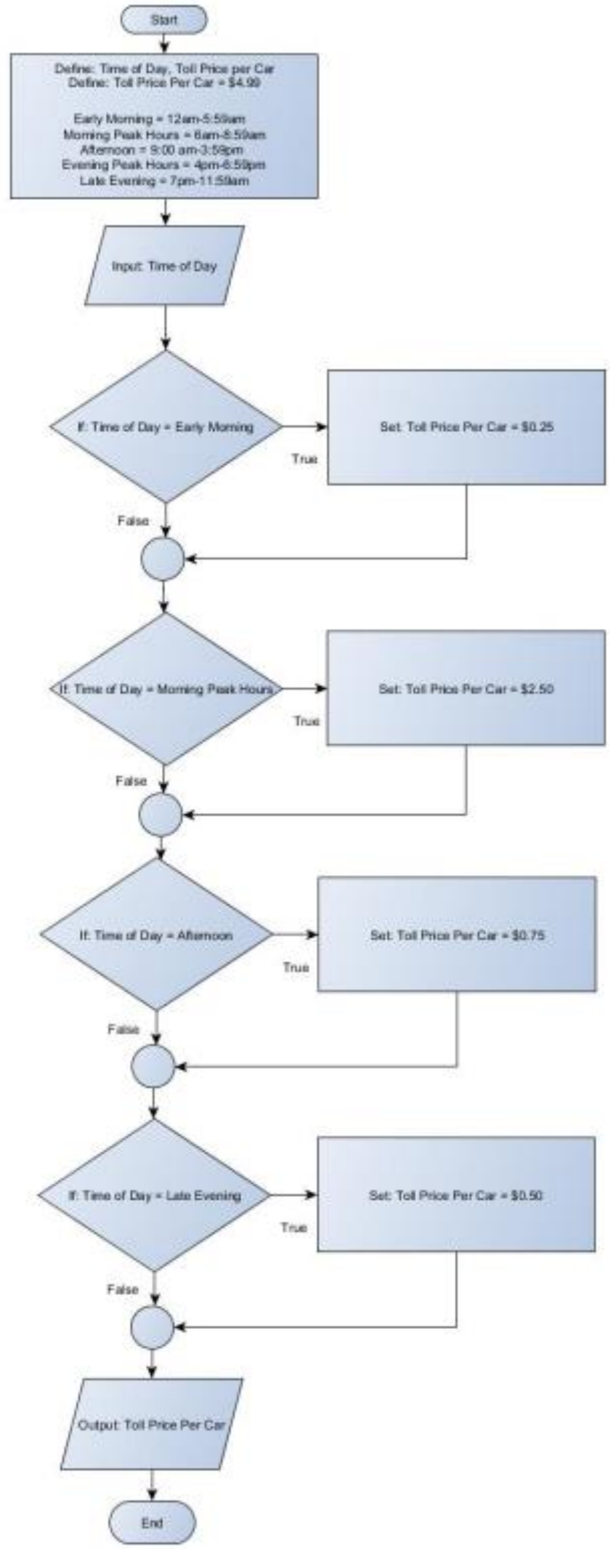
- Students could make a more complex flowchart for a process that can be posted around school in order to help describe a process (like a poster showing how to sort trash and recycling at lunch, how to raise the flags, or something similar. These could be placed around the school to help other visualize common processes.

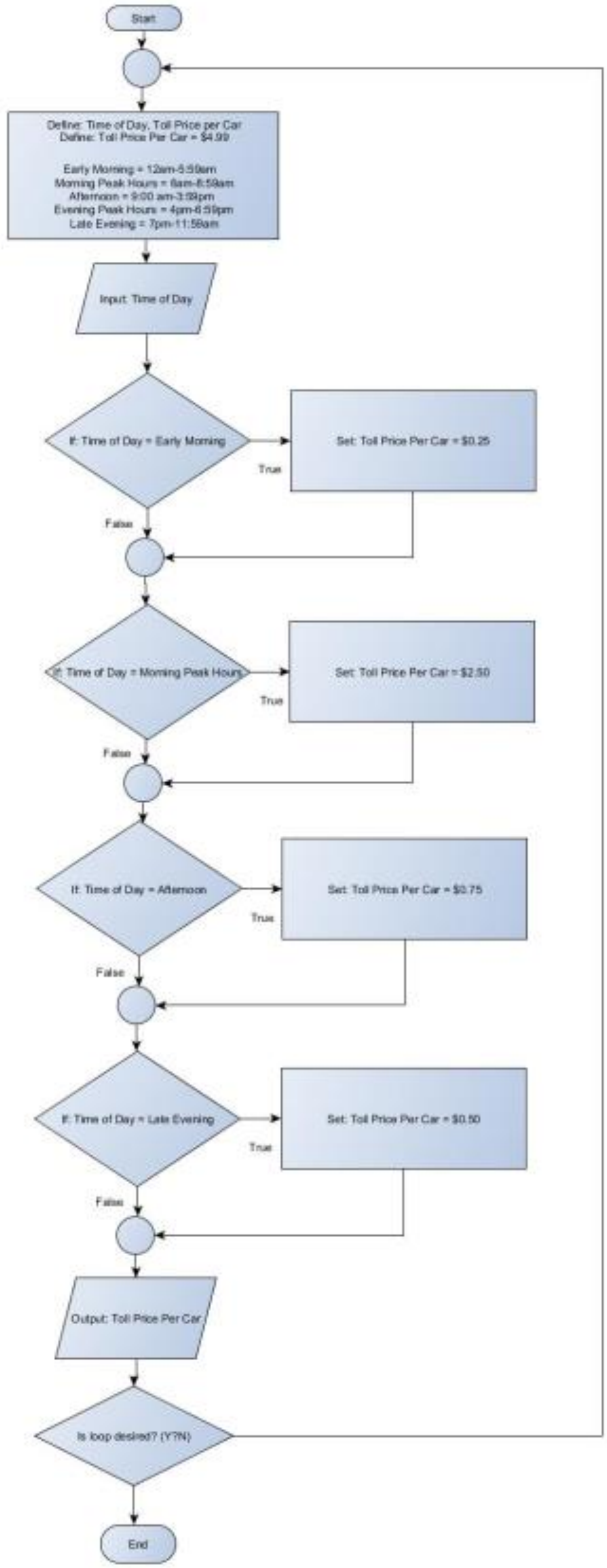
- Invite a representative from the DOT or local transportation agency to talk about congestion-based pricing.

- Utilize Edmodo (www.edmodo.com) to provide further questioning and discussion between students and teacher. Edmodo is safe social learning website made specifically for teachers and students. It is a way to collaborate on assignments, homework, projects, and after-school STEM programs and is used as a communication tool to provide additional questioning and feedback from teachers and students.
- Students can go to the following website for examples coding activities geared toward a middle and high school level: http://code.org/learn
- Teachers can go to the following website to learn how to implement the "hour of code" into your curriculum: http://hourofcode.com/us/resources/how-to
- Students can download and use a free flowcharting application called yEd Graph Editor via the following link. yEd was used to create the flowcharts found in this lesson. If possible (say, if there is a computer lab available), students could create their flowcharts for Activities 3 and 4 using yEd instead of by hand. http://www.yworks.com/en/products/yfiles/yed/.

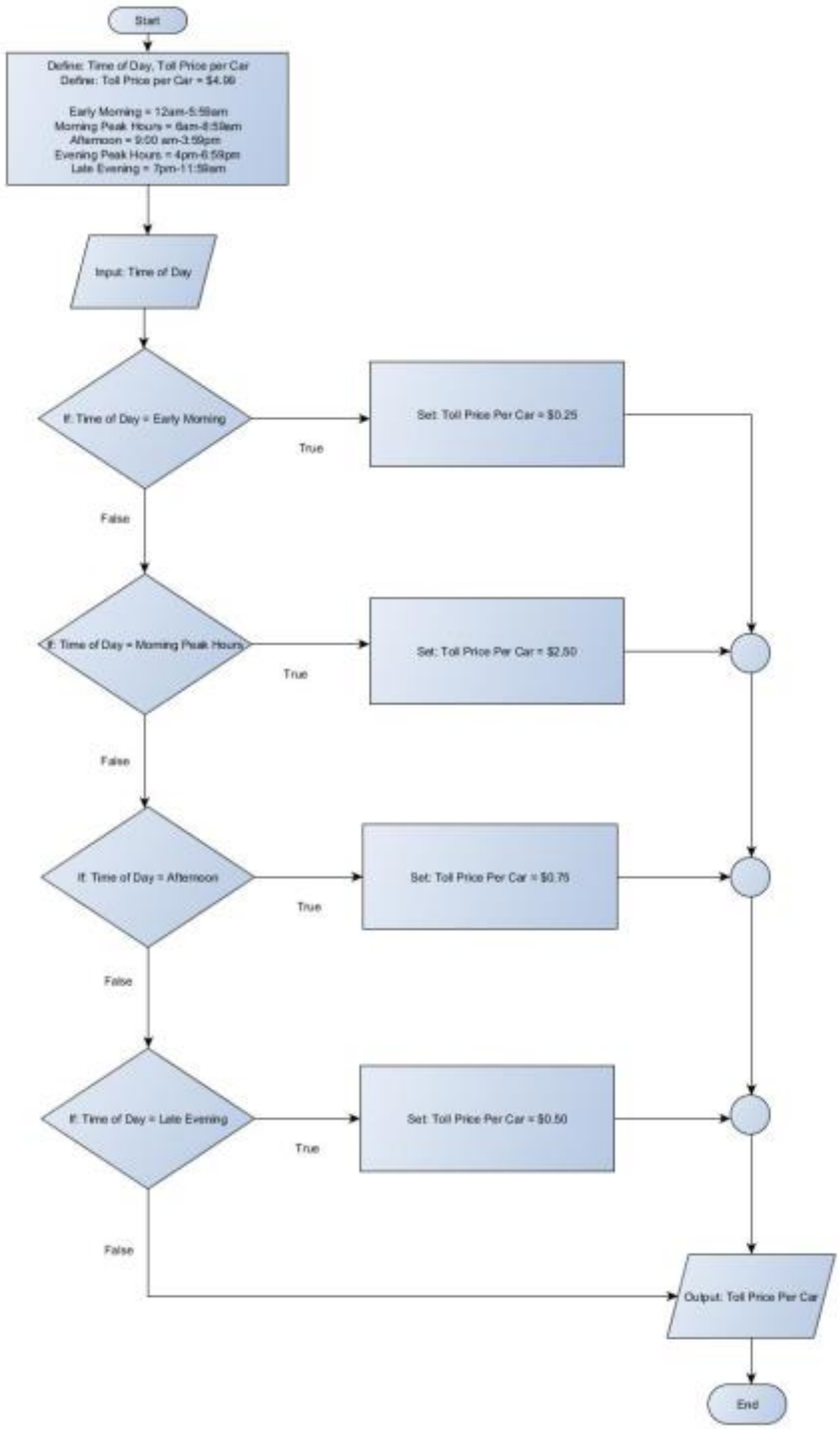
Appendix A – Stacked-If Congestion Pricing Flowchart

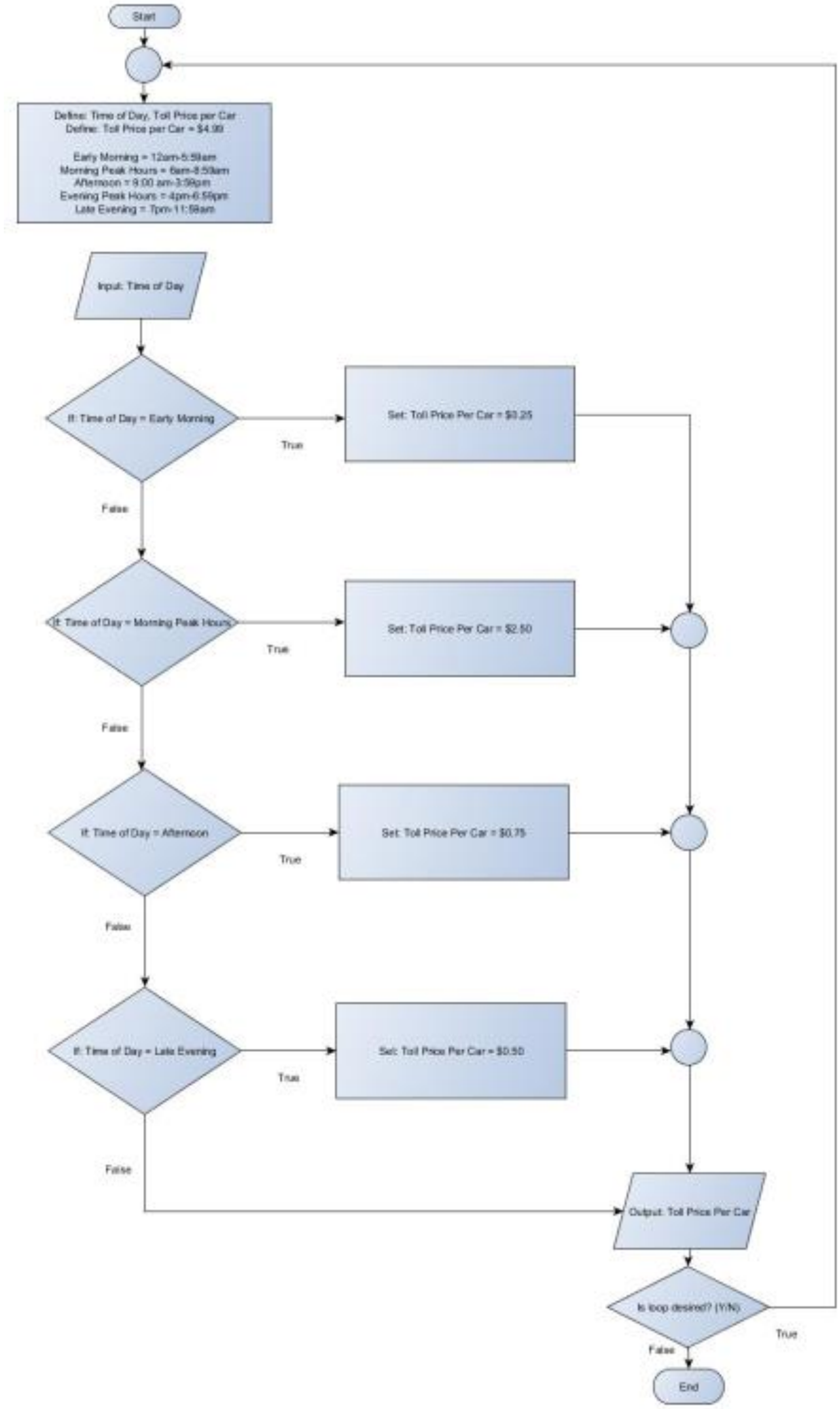
For both Appendix A and B, two flowcharts are shown. The second chart in each Appendix is exactly the same as the first chart, but with an added loop to represent the iterative nature of these processes.




Start
Define: Time of Day, Toll Price per Car
Define: Toll Price Per Car = $4.99
Early Morning = 12am-5:59am
Morning Peak Hours = 6am-8:59am
Afternoon = 9:00 am-3:59pm
Evening Peak Hours = 4pm-6:59pm
Late Evening = 7pm-11:59am
Input: Time of Day
If: Time of Day = Early Morning
True
Set: Toll Price Per Car = $0.25
False
If: Time of Day = Morning Peak Hours
True
Set: Toll Price Per Car = $2.50
False
If: Time of Day = Afternoon
True
Set: Toll Price Per Car = $0.75
False
If: Time of Day = Late Evening
True
Set: Toll Price Per Car = $0.50
False
Output: Toll Price Per Car
Is loop desired? (Y?N)
End

Appendix B – Nested-If Congestion Pricing Flowchart




Start
Define: Time of Day, Toll Price per Car
Define: Toll Price per Car = $4.99
Early Morning = 12am-5:59am
Morning Peak Hours = 6am-8:59am
Afternoon = 9:00 am-3:59pm
Evening Peak Hours = 4pm-6:59pm
Late Evening = 7pm-11:59am
Input: Time of Day
If: Time of Day = Early Morning
True
Set: Toll Price Per Car = $0.25
False
If: Time of Day = Morning Peak Hours
True
Set: Toll Price Per Car = $2.50
False
If: Time of Day = Afternoon
True
Set: Toll Price Per Car = $0.75
False
If: Time of Day = Late Evening
True
Set: Toll Price Per Car = $0.50
False
Output: Toll Price Per Car
Is loop desired? (Y/N)
True
False
End