ehp

LESSON:

Traffic Congestion Charging
Will It Improve Air Quality?

Summary Students read an article introducing the concept of urban street canyons. Then they analyze congestion pricing data, discuss air pollution control methods, and present their findings.

Lesson Type **Data Analysis**—students read and interpret data from graphs or figures.

***EHP* Article** Canyons Up the Pollution Ante
Environ Health Perspect 116:A289 (2008)
http://www.ehponline.org/docs/2008/116-7/forum.html#cany

Objectives By the end of this lesson, students should be able to

- calculate the percent change for specific air pollutant levels and number of cars in London as a result of the city's Congestion Charge scheme
- estimate potential air pollutant changes in New York City
- draw line graphs highlighting changes resulting from congestion pricing
- argue whether congestion pricing would be beneficial for New York City

Class Time 50 minutes

Grade Level Middle school, high school

Subjects Addressed Environmental Science, General Science, Physics/Physical Science, Social Studies

Aligning with Standards

SKILLS USED OR DEVELOPED

- Communication (note-taking, oral, written—including summarization)
- Comprehension (listening, reading)
- Computation
- Critical thinking and response
- Graphing
- Tables (reading)

SPECIFIC CONTENT ADDRESSED

- Air pollution
- Congestion pricing

NATIONAL SCIENCE EDUCATION STANDARDS MET

Science Content Standards

Unifying Concepts and Processes Standard

- Evidence, models, and explanation
- Change, constancy, and measurement

Science as Inquiry Standard

- Abilities necessary to do scientific inquiry

Science in Personal and Social Perspectives Standard

- Personal and community health
- Natural and human-induced hazards
- Environmental quality

National Institute of Environmental Health Sciences

Prepping the Lesson (15 minutes)

INSTRUCTIONS

1. Download the article "Canyons Up the Pollution Ante" at http://www.ehponline.org/docs/2008/116-7/forum.html#can.
2. Review Background Information, Implementing the Lesson, Assessing the Lesson, and Student Instructions for this lesson.
3. Make copies of the Student Instructions.

MATERIALS (per student)

- 1 copy of "Canyons Up the Pollution Ante," preferably in color
- 1 copy of the Student Instructions
- Calculator
- Pencil
- Graph paper

VOCABULARY

- air quality
- congestion pricing
- emissions
- intake fraction
- megacity
- mobile source
- nitrogen dioxide (NO_2)
- nitrogen oxides (NO_x)
- particulate matter (PM)
- pollution
- stationary source
- urban street canyon

BACKGROUND INFORMATION

Air Pollutants

Air pollution comes from both stationary sources (fixed locations such as factories and power plants) and mobile sources (such as buses, cars, planes, trains, and trucks). Pollutants may also originate from natural sources, such as volcanic eruptions. Through the Clean Air Act, the U.S. Environmental Protection Agency (EPA) established National Ambient Air Quality Standards, which establish levels of pollutants deemed harmful to public health and the environment. Six air pollutants are monitored: carbon monoxide, lead, particulate matter (PM), sulfur dioxide, volatile organic compounds, and a group of gases known as nitrogen oxides (NO_x). This lesson focuses on PM and a form of NO_x known as nitrogen dioxide (NO_2). Both PM and NO_x are measured in micrograms per cubic meter ($\mu g/m^3$) of air.

NO_x species are highly reactive gases that contain different amounts of nitrogen and oxygen (EPA 1998). NO_x contributes to acid rain, global warming, and smog (EPA 1998). NO_x affects the respiratory system and can cause and aggravate respiratory diseases such as asthma (EPA 1998). This lesson focuses specifically on NO_2 because data for that pollutant are readily available. Although most NO_x species are odorless and colorless, NO_2 has a reddish-brown color that can be seen in the air of many urban areas. The standard NO_2 limit to protect public health is 100 $\mu g/m^3$ averaged over a year (EPA 2008a).

PM is a mixture of liquid droplets and very small particles of soil, dust, acids, chemicals, and/or metals. Primary particles are emitted directly from a source, whereas secondary particles form in the atmosphere as a result of chemical reactions between chemicals such as NO_x and sulfur dioxide (EPA 2008b). Particles are classified according to size. PM_{10} refers to particulates with a diameter of 2.5–10 micrometers, and $PM_{2.5}$ refers to particulates with a diameter smaller than 2.5 micrometers (EPA 2003). Both types of PM can enter deep into the lungs and even the bloodstream due to their small size. Short-term, or acute, exposure to PM is linked to irritation of the eyes, nose, and throat as well as aggravated symptoms of respiratory and cardiovascular diseases (EPA 2003). Long-term ("chronic") exposure is linked to diminished lung function, chronic bronchitis, and early death (EPA 2003). The standard PM_{10} limit to protect public health is 150 $\mu g/m^3$ averaged over 24 hours, a value not to be exceeded more than once per year averaged over 3 years (EPA 2008a). The standard $PM_{2.5}$ limit to protect public health is 15 $\mu g/m^3$ averaged over a year; to meet this standard, the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from one or more monitors must not exceed 15 $\mu g/m^3$ (EPA 2008a).

Congestion Pricing

Several cities have implemented congestion pricing systems to reduce traffic congestion and improve air quality and health outcomes. Revenue from congestion pricing may be used to improve each city's public transportation systems. Drivers are charged a

small fee to enter specific sections of several cities around the world. Singapore was the first city to implement congestion pricing with its Area Licensing Scheme (ALS) in 1975 (Santos 2005). In 1998 the ALS was replaced by the Electronic Road Pricing (ERP) program (Santos 2005). London's Congestion Charge scheme was introduced in 2003 and expanded in 2007 (Tonne et al. 2008). The Stockholm Trial pricing scheme began in 2006 (City of Stockholm Environment and Health Administration 2006). Studies comparing air quality before and after congestion pricing systems went into effect have been conducted in London and Stockholm; however, data from Singapore are scarce. Data from London are included in this lesson because London and New York have similar population sizes. The London data are from external sources, including government reports and peer-reviewed journals.

London's Congestion Charge scheme is considered a success; the number of vehicles and congestion within the charging zone has decreased. Between 2006 and 2007, the pricing scheme generated £123 million (approximately US$224 million), which is being used to improve transportation—including buses, roads, bridges, and road safety and pedestrian programs—throughout London. The number and severity of vehicle accidents have decreased (Transport for London 2007).

There have been attempts to implement a congestion pricing system in the United States, most recently in New York City, but none have been successful yet. Opponents of congestion pricing are concerned that although air quality, health outcomes, and traffic may improve within the congestion pricing area, no or opposite effects may occur in the surrounding areas as more vehicles would be present in the areas just outside the congestion zone. In the case of London, pollutant levels decreased outside of the congestion zone but not as much as inside the pricing area (Transport for London 2007). The tracking systems used to document vehicles entering the pricing area also pose concerns about privacy and civil liberties. Finally, a congestion charge is viewed as an additional financial burden for drivers.

References

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U.S. Environmental Protection Agency. 2003. Particle pollution and your health. EPA-452/F-03-001. http://www.epa.gov/oar/particlepollution/pdfs/pm-color.pdf

U.S. Environmental Protection Agency. 2008a. National Ambient Air Quality Standards (NAAQS). http://www.epa.gov/air/criteria.html

U.S. Environmental Protection Agency. 2008b. Particulate matter: basic information. http://www.epa.gov/air/particlepollution/basic.html

RESOURCES

Environmental Health Perspectives, Environews by Topic page. http://ehp.niehs.nih.gov/. Choose Air Pollution, Economics

AirNOW (provides local air quality data for the United States). http://www.airnow.gov/

Singapore Land Transport Authority. Electronic Road Pricing. http://www.lta.gov.sg/motoring_matters/index_motoring_erp.htm

Stockholmsförsöket. The Stockholm Trials. http://www.stockholmsforsoket.se/templates/page.aspx?id=183

Transport for London. Congestion Charging. http://www.tfl.gov.uk/roadusers/congestioncharging/default.aspx

U.S. Environmental Protection Agency. Where you live (provides local air quality trends for common pollutants). http://www.epa.gov/airtrends/where.html

Implementing the Lesson

INSTRUCTIONS

1. Have students read the article "Canyons Up the Pollution Ante." Discuss the vocabulary and content of the article as needed to help students understand the main idea of the research discussed in the article. Highlight NO_2 and PM_{10} as air pollutants (see Background Information).

2. Inform students they will be doing an activity to see some effects of congestion pricing and whether they think congestion pricing could be an effective plan to reduce air pollution in other places, such as New York City. You may want to brainstorm with students other strategies for reducing air pollution—such as better urban planning, increased mass transportation, or stricter air pollution standards—and compare the pros and cons to these approaches.

3. Distribute the Student Instructions and have students complete the calculations and answer the questions. Discuss the results as a class. Your students may ask if the results of congestion pricing on air quality are low. Tell your students that although vehicle emissions decreased (NO_x dropped by 17.3% and PM_{10} by 23.8%), the overall change in air concentrations of NO_x and PM_{10} was only an approximate 1% decrease. Several factors may contribute to the modest nature of the improvements in air quality. Vehicle emissions are only one part of overall air quality; industrial, domestic, and personal (e.g., fireplace) emissions also contribute. Weather and climate conditions can also affect air quality. The location of monitoring stations can also affect emission changes and measured air quality. For example, one monitor may be located next to a bridge with heavy traffic, while another is located on a road with less traffic. Finally, congestion pricing is executed for just a few hours each day, which may not be long enough to affect overall air quality.

4. Divide the class into small groups of 3–5 students each. Each group should decide whether they would agree with implementing a congestion pricing plan in New York City.

5. Have groups present their decisions and supporting reasons to the class.

NOTES & HELPFUL HINTS

- Students could research the potential effects of congestion pricing in their own cities or other cities besides New York City.
- Students could debate whether congestion pricing plans should be implemented.
- Students could research other ways to reduce air pollution and investigate how such changes have affected air quality. They could even conduct a cost–benefit analysis of the other approaches. A cost–benefit analysis should consider who pays and how (e.g., is payment in the form of fines to businesses, use of taxes, or one-time or ongoing charges to individuals?).
- If time is short, students can write a persuasive argument in favor of or against congestion pricing for homework.

Assessing the Lesson (steps not requiring teacher feedback are not listed below; see Student Instructions for complete step-by-step instructions)

Step 2 **Examine the annual mean concentrations of NO_2 and PM_{10} in London before and after the city's Congestion Charge scheme was established. Complete Table 1 below and show your work. In the "+ or –" column place a plus (+) if there was an increase in the amount of pollution after implementing congestion pricing or a minus (–) if there was a decrease in the amount of pollution.**

Table 1: Congestion Pricing and Air Pollution, London

	Before (μg/m^3)	After (μg/m^3)	Change (μg/m^3)	+ or –	% Change
NO_2	54.72	53.99	0.73	–	1.3
PM_{10}	30.31	30.06	0.25	–	0.8

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NO_2 Change (μg/m^3): 54.72 – 53.99 = 0.73

NO_2 Change (%): 0.73 / 54.72 = 0.013
0.013 × 100% = 1.3%

Or:

53.99 / 54.72 = 0.9866
1 – 0.986 = 0.013 × 100% = 1.3%

PM_{10} Change (μg/m^3): 30.31 – 0.25 = 30.06

PM_{10} Change (%): 0.25 / 30.31 = 0.008
0.008 × 100% = 0.8%

Or:

30.06 / 30.31 = 0.991
1 – 0.991 = 0.008 × 100% = 0.8%

Step 3 **Table 2 below shows the change in the number of vehicles entering London's congestion zone from pre-pricing in 2002 to post-pricing in 2006. Complete Table 2 and show your work.**

Table 2: Congestion Pricing and Number of Vehicles, London

	Before	After	Change	+ or –	% Change
No. cars	378,000	316,000	62,000	–	16

After: 378,000 – 62,000 = 316,000

% Change: 62,000 / 378,000 = 0.16
0.16 × 100% = 16%

Step 4 **The New York City Congestion Pricing Plan proposes to charge a fee for cars to enter Manhattan below 60th Street between the hours of 6 AM and 6 PM. Apply the % Change values you calculated in Steps 2 and 3 to estimate the potential effects in New York City.**

a. Complete Table 3 below using the % Change values from Table 1. Show your work.

Table 3: Potential Congestion Pricing and Air Pollution, New York City

	% Change in London	+ or –	Before (μg/m^3)	After (μg/m^3)	Change (μg/m^3)
NO_2	1.3	–	68	67.12	0.88
PM_{10}	0.8	–	24	23.81	0.19

NO_2 After (μg/m^3): 68 – 0.88 = 67.12
NO_2 Change (μg/m^3): 68 × 0.013 = 0.884

PM_{10} After (μg/m^3): 24 – 0.19 = 23.81
PM_{10} Change (μg/m^3): 24 × 0.008 = 0.192

b. Complete Table 4 below using the % Change value from Table 2. Show your work.

Table 4: Potential Congestion Pricing and Number of Cars, New York City

	Before	After	Change	+ or –	% Change
No. cars	1,529,815	1,285,045	244,770	–	16

Change: 1,529,815 × 0.16 = 244,770

After: 1,529,815 – 244,770 = 1,285,045

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c. The New York Plan would charge $8 per car to enter the congestion area. Use the After value calculated in Step 4b to determine how much money would be made as a result of congestion pricing. Show your work.

1,285,045 × $8 = $10,280,360

d. List three ways you think this money could be used.

Students should identify realistic ways the money could be used, such as improving mass transportation, providing rebates to people who live in the city, paying for additional employees in understaffed city departments, greening the city, supporting city schools and/or shelters, etc.

Step 5 **List three potential advantages and three potential disadvantages of congestion pricing.**

Advantages	Disadvantages
Better air quality	Not everyone benefits
Better health outcomes	More expensive to drive
Less traffic	Loss of privacy
Fewer traffic accidents	Requires large public transportation system
Better public transportation	

Step 6 **If you were a member of the New York Assembly, would you approve the proposed New York City Congestion Pricing Plan? Why or why not?**

Students should provide a persuasive argument for whether or not congestion pricing would be beneficial and/or effective in New York City using the information they have obtained.

Step 7 **Do you think congestion pricing would work in a big city near you? Why or why not?**

Students should provide a persuasive argument for whether or not congestion pricing would be beneficial and/or effective in a city near them using the information they have obtained.

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STUDENT INSTRUCTIONS:

Traffic Congestion Charging
Will It Improve Air Quality?

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c. The New York Plan would charge $8 per car to enter the congestion area. Use the After value calculated in Step 4b to determine how much money would be made as a result of congestion pricing. Show your work.

d. List three ways you think this money could be used.

Step 5 List three potential advantages and three potential disadvantages of congestion pricing:

Advantages	Disadvantages

Step 6 If you were a member of the New York Assembly, would you approve the proposed New York City Congestion Pricing Plan? Why or why not?

Step 7 Do you think congestion pricing would work in a big city near you? Why or why not?