

Evaluating Evidence

Activity Overview

Students are asked to determine a final transportation route for shipping the barrels of simulated hazardous waste. Students use the DOT data from Activity 7, “Transporting Hazardous Materials,” to help them evaluate the different transportation options. In choosing a route, they also consider several other factors in addition to safety. Students are asked to support their recommendation with evidence and identify the trade-offs of their decision.

CONCEPTS, PROCESSES, AND ISSUES

(with NSE 5–8 Content Standards Correlation)

1. Hazardous materials are substances that pose a danger to the health and safety of living organisms. (*PhysSci: 1*)
2. Hazardous materials must be identified and labeled before being treated, moved, or disposed of. (*Perspectives: 4*)
3. Analysis of data can aid in the assessment of options, risk, and trade-offs and facilitate decision making related to transportation of hazardous materials. (*Inquiry: 1; SciTech: 1; Perspectives: 4*)
4. Mathematical calculations can provide quantitative evidence. (*Inquiry: 1*)

TEACHING SUMMARY

Step 1.

Brainstorm factors that might be important to consider when transporting hazardous materials.

Step 2.

Evaluate different types of evidence.

Step 3. (Assessment)

Recommend a final transportation route.

MATERIALS

For the teacher

- 1 Transparency 1.4, “Feedback Form: Analyzing Data” (optional)
- 1 Transparency 1.5, “Scoring Guide: Analyzing Data” (optional)
- * 1 overhead projector

For each student

- Data from Investigation 7, “Planes, Trains, and More”
- 1 Student Sheet 8.1, “Transportation Map”
- 1 Student Sheet 8.2, “Calculating Costs” (optional)
- 1 paper copy of Transparency 1.4, “Feedback Form: Analyzing Data” (optional)
- 1 paper copy of Transparency 1.5, “Scoring Guide: Analyzing Data” (optional)

*not supplied in kit

Teaching Suggestions

GETTING STARTED

Step 1. Brainstorm factors that might be important to consider when transporting hazardous materials.

During Investigation 7, “Planes, Trains, and More,” students recommended a mode of transportation for transporting hazardous waste based primarily on safety data. Ask, *What other factors do you think a company might consider before shipping hazardous waste?* Students are likely to suggest such factors as cost and time required to ship materials. Encourage students to think of as many other factors as possible.

Remind students that, at the beginning of this module, they investigated a situation where a barrel of

hazardous waste needed to be identified and disposed of. Explain that, in this activity, they will consider several factors related to transportation of hazardous materials before deciding on a plan to ship the waste for disposal.

INVESTIGATING

Step 2. Evaluate different types of evidence.

Distribute Investigation 8, “The Right Route,” and have students read the introduction. Part of the introduction establishes the scenario in which students are asked to make a recommendation to Tidy Transport, the company that will transport the waste to a disposal facility. Remind students to use their science notebooks to record information, calculations, data tables, and ideas, beginning with any relevant information from the introduction.

Hand out Student Sheet 8.1, “Transportation Map.” Ask, *What information does the map provide?* If necessary, review how to read a map by highlighting some of this map’s important features, such as the air route and the river. Students are then asked to consider which route from Toxic City to Cleanville seems to be the best. Initially, students may or may not base their choices on evidence, such as the safety data from Investigation 7, “Planes, Trains, and More.”

In Procedure Step 2, students are specifically asked to reconsider the safety data and recommend a route based solely on safety. In Investigation 7, students calculated that the smallest percentage of accidents

occurred during highway transport, and the smallest percentage of injuries occurred during water transport.

In Procedure Step 3, students are asked to calculate the total distance that the barrels must travel via different possible routes. A completed table is shown at the bottom of the page. Encourage students to think about why transporting the barrels over a shorter distance might be preferable to transporting them over a longer distance. Students are likely to recognize that the possibility of an accident increases the farther the barrels have to travel and the longer the barrels are in transit. From this perspective, air transportation is a better choice because it transports the waste over the shortest distance (and most probably in the shortest amount of time).

Procedure Step 4 introduces the factor of cost. In addition to the cost per mile, students are asked to calculate the cost per route. They can do this by multiplying the distance of a particular segment by the cost of a particular mode of transportation. The cost of each segment in the route must then be totaled. For example, transportation by railroad is estimated to cost a total of \$17,000, as explained in Investigation 8. You may wish to provide students with Student Sheet 8.2, “Calculating Costs,” which provides blank tables that students can use to complete these calculations. The calculations for the other possible routes are shown on the next page. If cost were the only factor under consideration, transporting the waste along Scenic Highway would appear to be the best decision.

Sample Responses to Possible Routes Table (Procedure Step 3)

| Complete Route from Toxic City to Cleanville | Total Distance (in miles) | Primary Mode of Transportation |
|--|-------------------------------------|--------------------------------|
| Route 2, railroad, Route 4 | $60 + 500 + 40 = 600$ | rail |
| Route 2, Interstate Highway, Route 4 | $60 + 183 + 450 + 267 + 40 = 1,000$ | highway |
| Route 2, Rolling River, Route 4 | $35 + 580 + 13 = 628$ | ship |
| Road to airport, airplane, road from airport | $3 + 480 + 7 = 490$ | airplane |
| Scenic Highway | 550 | highway |

Sample Responses to Student Sheet 8.2, “Calculating Costs” (Step 4)

Route: Route 2, Interstate Highway, Route 4

| Route | Distance | Cost | Total |
|-------------|-------------|------|----------|
| All highway | 1,000 miles | \$20 | \$20,000 |
| Total cost | | | \$20,000 |

Route: Route 2, Rolling River, Route 4

| Route | Distance | Cost | Total |
|-----------------------|-----------|------|----------|
| Route 2 to river | 35 miles | \$20 | \$ 700 |
| River | 580 miles | \$50 | \$29,000 |
| Route 4 to Cleanville | 13 miles | \$20 | \$ 260 |
| Total cost | | | \$29,960 |

Route: Road to Airport, Airplane, Road from Airport

| Route | Distance | Cost | Total |
|-------------------|-----------|------|----------|
| Road to airport | 3 miles | \$20 | \$ 60 |
| Airplane | 480 miles | \$70 | \$33,600 |
| Road from airport | 7 miles | \$20 | \$ 140 |
| Total cost | | | \$33,800 |

Route: Scenic Highway

| Route | Distance | Cost | Total |
|-------------|-----------|------|----------|
| All highway | 550 miles | \$20 | \$11,000 |
| Total cost | | | \$11,000 |

In Procedure Step 5, the question of cost is made more complex by the suggestion of a budget and the future impact of going over budget. Without such parameters, students are likely to choose the safest route, regardless of cost. However, most real-world decisions take other factors into account, including financial impacts. Step 5 attempts to guide students into addressing the trade-offs involved in complex decision making.

Procedure Step 6 raises the issue of public concerns, another factor that often affects real-world decisions. Although many other factors could be brought into play, this scenario asks students to address the factors of safety, cost, distance, and public concerns.

SYNTHESIZING

Step 3. (Assessment) Recommend a final transportation route.

In their groups of four, have students discuss the Group Analysis Questions. You can then discuss the questions as a whole class. Highlight the different factors that can be used to decide on a route, and how different students may evaluate these factors.

Before assigning Question 4, you may need to provide guidance on how to develop a complete response. Discuss the types of information that can be used as evidence. After students have responded to all of the questions, you may wish to have the class vote to choose a single transportation route.

QUESTION 1

Was your initial recommendation (the one that you made in Step 1) the same as your final recommendation (the one that you made in Step 7)? Why or why not?

Some students will make the same recommendation at both the beginning and end of this activity because they consider safety to be the most important factor, regardless of other factors. Other students may change their recommendations to take into account other factors or because they did not give sufficient thought to their initial recommendations.

QUESTION 2

If you were a resident of Tourist Town, would you support the transport of this hazardous material through your town? Why or why not?

Most students likely would not support the transport of hazardous materials through the town, particularly if the route is close to their own neighborhood. Students may be concerned about the risk of an accident and the possibility that the environment could be permanently contaminated. Residents may be concerned about the effect of trucks with hazardous placards going through the town on tourism, which could possibly damage the town's economy. Depending on the frequency of the trucks, the trucks could also add to noise and traffic congestion in the town.

Other students may not be as concerned, pointing out that they are surrounded by hazardous substances and that the people and businesses in the town probably use a variety of hazardous substances every day. In fact, the town is likely to receive some shipments of hazardous materials for essential goods and services. With the proper safety precautions, the shipment of hazardous materials through the town could become routine.

Some students may say that they would like to know the exact hazards posed by the materials, the volume of materials being shipped, and the frequency of shipments before making a final decision. For example, a single shipment of toxic materials may be acceptable, but daily shipments of flammable waste may be considered too dangerous. Encourage students to discuss which risks are considered acceptable and why.

QUESTION 3

- a. *Which factor do you think is the most important in deciding how to transport hazardous waste?*

Many students are likely to consider safety the most important factor, though some students may also consider cost, distance, or public concerns to be the most important.

- b. *Do you think that decisions can be made based on this one factor alone? Why or why not?*

Students should begin to realize that thoughtful decisions require the consideration of multiple factors. Even if one factor is given more weight, the final decision is affected by other relevant factors. For example, making a decision based solely on safety might compromise future safety or might cost more than people can afford (or are willing) to pay.

QUESTION 4 (Assessment)

Recommend a route for transporting the barrels from Toxic City to Cleanville. Support your recommendation with evidence.

Although student responses will vary, guide students to support their answers with evidence. Students may also identify other types of infor-

mation that could be helpful, such as the time required to transport the materials from one place to another; the safety record of the transportation company; the number of trucks, rail cars, planes, or ships needed to hold all of the barrels; and the local weather. A complete and correct Level 3 response is shown here.

I would recommend the highway route following Route 2, Interstate Highway, and Route 4. It's safe, cheap, and avoids Tourist Town. The highway is the safest mode of transportation, with an accident rate of 1.2%. This is lower than the rate for any of the other transportation modes. It would help to know whether the highway in this area is more dangerous than the other routes because of local conditions (like really curvy roads). The highway also is one of the cheaper options, at \$20,000. Using Interstate Highway also avoids Tourist Town, which should make the people of the town happy.

QUESTION 5

What are the disadvantages of your recommendation compared to the other possible routes?

Student responses will vary based on their recommended routes; a sample response is shown here.

The disadvantage of taking this highway route is that spending \$20,000 means going over budget by \$2,000. I don't think that \$2,000 will affect the number of future HAZMAT clean-ups by too much. Another disadvantage is that this route is the longest (1,000 miles). This means that the risk could be higher because the waste will be on the road for a longer distance and probably a longer period of time.

The Right Route

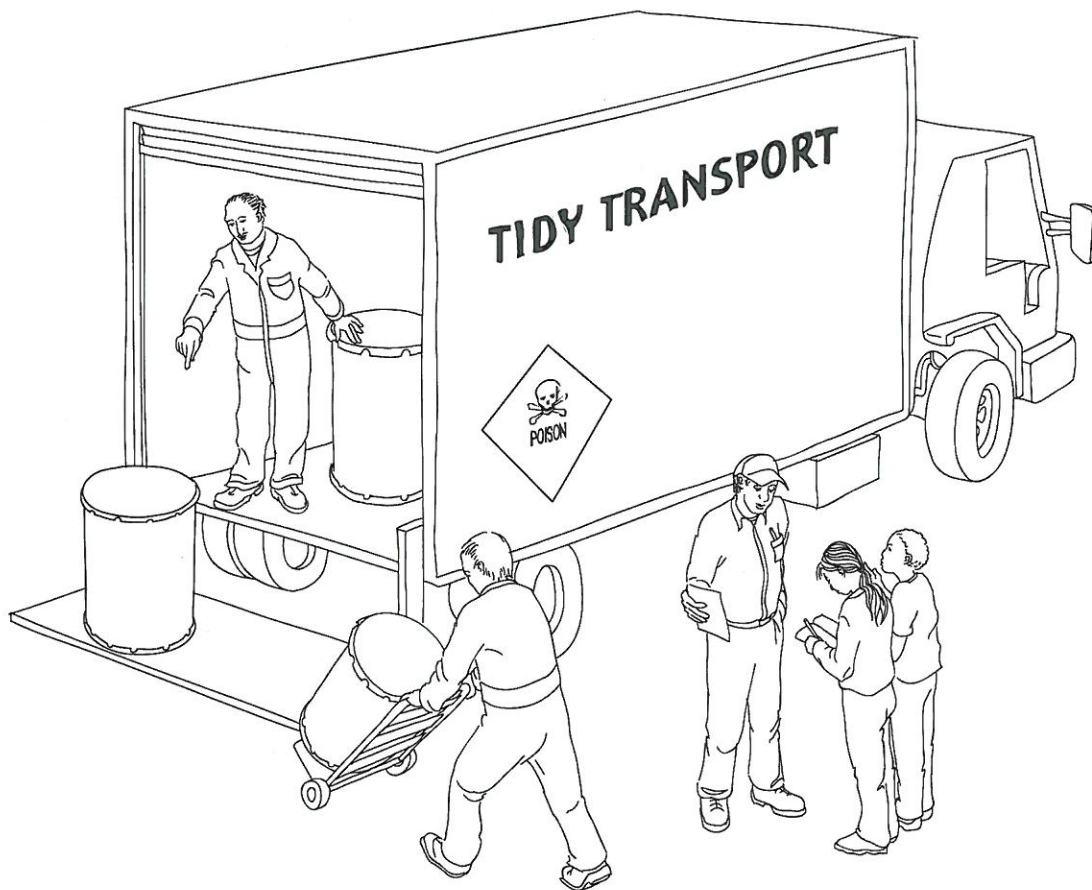
••••► CHALLENGE

What are the most important factors when deciding how to transport hazardous waste?

In Investigation 7, “Planes, Trains, and More,” you used safety data to decide how to transport hazardous waste. Decisions involve many factors, including cost, convenience, and public opinion. What will you do when factors besides safety need to be considered?

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There are 100 barrels of hazardous waste in Toxic City. They need to be transported to a hazardous waste disposal facility in Cleanville, which is about 600 miles away. Your HAZMAT team has hired the Tidy Transport Company to move the waste. Tidy Transport has asked your team to decide how you would like the barrels moved. In this investigation, you will evaluate information to help you make this decision.



MATERIALS*For each student***Data from Investigation 7, "Planes, Trains, and More"****I Student Sheet 8.1, "Transportation Map"****••••► PROCEDURE**

1.
 - a. Look at the map on Student Sheet 8.1, "Transportation Map." Identify all of the possible routes from Toxic City to Cleanville.
 - b. Discuss with your group which route you would recommend based on the map alone. Record your response in your science notebook.
2.
 - a. Review the DOT data from Investigation 7, "Planes, Trains, and More."
 - b. Discuss with your group which route you would recommend based on safety alone. Record your response in your science notebook.
3.
 - a. Create a table like the one below and describe the possible routes for transporting the waste between Toxic City and Cleanville. One route has been completed for you.
 - b. Discuss with your group why transporting the waste over a shorter distance might be better than transporting it over a longer distance.
 - c. Discuss with your group which route you would recommend based on distance alone. Record your response in your science notebook.

Possible Routes

| Complete Route from Toxic City to Cleanville | Total Distance (in miles) | Primary Mode of Transportation |
|--|---------------------------|--------------------------------|
| Route 2, railroad, Route 4 | $60 + 500 + 40 = 600$ | rail |
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4. a. Different modes of transportation can cost different amounts. Look at the following table, which shows how much Tidy Transport will charge to transport the barrels by four different modes of transportation.

Tidy Transport Charges

| Mode of Transportation | Cost per Mile |
|------------------------|---------------|
| Airplane | \$70 |
| Highway | \$20 |
| Railway | \$30 |
| Ship | \$40 |

- b. Use the transportation costs to determine the cost to transport the barrels by each route. Create a table like the one below to record your calculations. One route has been completed for you.

Route: Route 2, Railroad, Route 4

| Route | Distance | Cost | Total |
|-----------------------|-----------|------|----------|
| Route 2 to railroad | 60 miles | \$20 | \$ 1,200 |
| Railroad | 500 miles | \$30 | \$15,000 |
| Route 4 to Cleanville | 40 miles | \$20 | \$ 800 |
| Total cost | | | \$17,000 |

- c. Discuss with your group which route you would recommend based on cost alone. Record your response in your science notebook.
5. a. Your HAZMAT team has \$18,000 available to transport the waste. You may spend more than this amount, but any additional money that you spend will reduce the amount you have to spend on responding to hazardous materials spills in the future.
- b. Discuss with your group how your budget will affect your recommendation. Record your response in your science notebook.

6.
 - a. Scenic Highway passes through Tourist Town. The people of Tourist Town are very worried about the possibility of an accident and do not want the waste transported through their town. The town has a population of 25,000 people. It is a very popular place to visit in the summer. In the summer, the town's population can swell to 34,000 people.
 - b. Discuss with your group how this information about Tourist Town will affect your recommendation. Record your response in your science notebook.
7. Discuss with your group which route you think is best for transporting the barrels.

••••► ANALYSIS

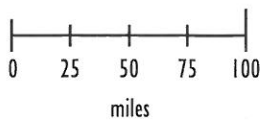
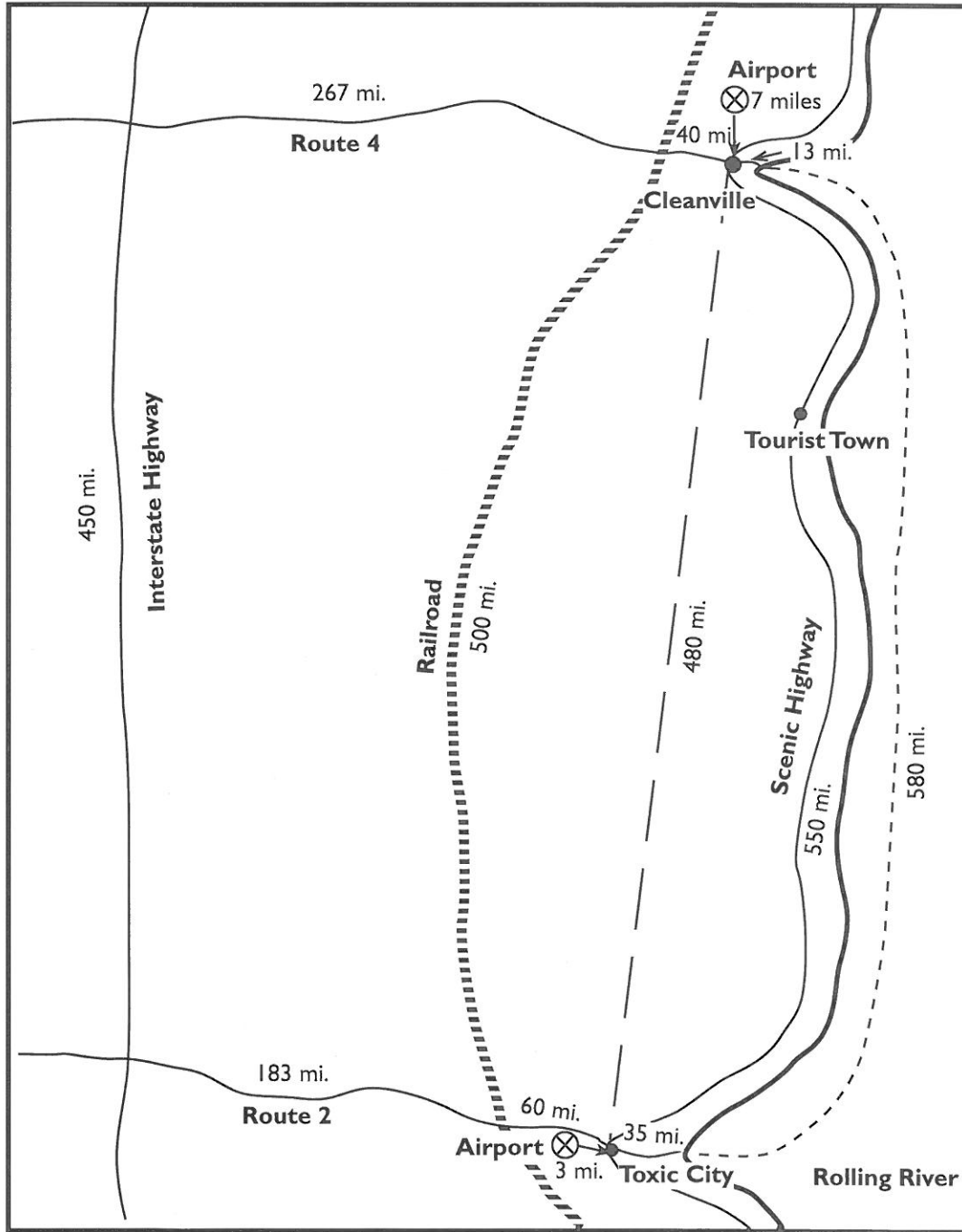
Group

1. Was your initial recommendation (the one that you made in Step 1) the same as your final recommendation (the one that you made in Step 7)? Why or why not?
2. If you were a resident of Tourist Town, would you support the transport of this hazardous material through your town? Why or why not?

Individual

3.
 - a. Which factor do you think is the most important in deciding how to transport hazardous waste?
 - b. Do you think that decisions can be made based on this one factor alone? Why or why not?
4. Recommend a route for transporting the barrels from Toxic City to Cleanville. Support your recommendation with evidence.
5. What are the disadvantages of your recommendation compared to the other possible routes?

Transportation Map



Calculating Costs

Route: _____

| Route | Distance | Cost | Total |
|-------------------|----------|------|-------|
| | | | |
| | | | |
| | | | |
| Total cost | | | |

Route: _____

| Route | Distance | Cost | Total |
|-------------------|----------|------|-------|
| | | | |
| | | | |
| | | | |
| Total cost | | | |

Route: _____

| Route | Distance | Cost | Total |
|-------------------|----------|------|-------|
| | | | |
| | | | |
| | | | |
| Total cost | | | |

Route: _____

| Route | Distance | Cost | Total |
|-------------------|----------|------|-------|
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