THE FREEWAY GAME

A TEACHING NOTE

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SIMULATION DESCRIPTION AND LEARNING OBJECTIVES

When deciding whether to get on the freeway during rush hour, did you ever stop to consider that if you did so, you would slow everybody ELSE down? When we ask our students that question, they typically laugh–their only consideration is how long it will take for their own trip. When a decision maker does not account for all the costs or benefits associated with the decision, there exists what economists call an 'externality.' Externalities are commonplace, and cause many problems in business and society. For example, excessive pollution, traffic congestion and the overexploitation of natural resources are all aggravated by negative externalities. Education, basic R&D and public safety are under-provided because the sponsors of these activities have to share the benefits with other people (i.e., they generate positive externalities). Network externalities, that result from the effect of people joining a network, can be either beneficial, for example if the addition of new members benefit other people in the network (positive externality), or detrimental, if increased membership causes the network to underperform (negative externality).

The Freeway Game is an online, multiplayer game that simulates traffic congestion to illustrate a negative externality. The game was designed as an in-class activity to introduce students in business and economics to the topic of externalities. In Wood's (2007) taxonomy of online games, the Freeway Game belongs to the category of "Insight" games, the purpose of which is to provide context and motivation for the lesson being taught. Hopefully, playing the game creates a 'A-Ha moment!'

The game was designed to accomplish the following learning outcomes: After playing and debriefing the game, the students should be able to:

1. Understand what an externality is and recognize its impact in the business world;
2. Understand the role regulations may play in correcting the undesirable effects;
3. Propose other corrective measures and argue in their favor.

GAME SYNOPSIS

The Freeway Game is based on a common situation with which most if not all students will have familiarity, that of traffic congestion. When a person enters a congested freeway, she creates a negative externality on all other drivers, in that she slows everyone else down. Yet, nobody (that we know of) routinely takes this externality into account when they decide whether or not to access the freeway; the decision is made on the basis of personal travel time (not on the basis of someone else's travel time). After students experience the over-congestion that is created on a toll-less freeway, a toll is introduced into the game to show students how this can lead to the socially-optimal solution. Students are subsequently asked to brainstorm other possible solutions, and to think of other examples where externalities are prevalent.

WHEN TO USE THE FREEWAY GAME

The game is appropriate for undergraduate and graduate education, including executive education.

The game is a good fit for lectures dealing with externalities, environmental policy and public goods. It is also suitable for courses dealing with the social impacts of business, e.g., sustainability, corporate social responsibility, ethics, and supply chain management. The game can also be used in game theory courses.

The game is played as a prolog to a lecture. Instructors should schedule about 30 minutes to play the game from start to finish, and another 30 minutes to debrief the students.

WHAT YOU WILL NEED TO PLAY THE GAME

The instructor will need a laptop or desktop connected to the Internet and a video-projector. The instructor's screen should be projected on the big screen for everyone to see.

The instructor also needs to provide a token prize to reward the winner.

Students can connect to the game using a computer, smartphone or tablet. The game uses standard Internet protocols (html, php, javascript and jquery). No plug-ins or add-ons are required. The following popular browsers are fully supported: Chrome, Firefox, Internet Explorer and Safari.

PLAYING THE GAME

The game is freely available at *http://www.thefreewaygame.com*. This website is for instructors and students alike. The number of players is not limited; and in fact given the nature of the game, more players is actually desirable. (For a meaningful experience, we recommend at least eight players.)

The game is played for about 30 rounds. Each round represents a day. Each day, the students have to decide whether to (i) take the freeway or (ii) take the back roads for their commute to the city. The travel time on the back roads is always exactly 30 minutes. The travel time on the freeway depends on traffic. It could be as low as 15 minutes when there is no traffic; but it could rise to 45 minutes if all students take the freeway. (The detailed formula is given below).

The students' time is valued at $20 per hour. Thus, the travel cost is always $10 on the back roads, and between $5 and $15 on the freeway (excluding any tolls).

The game unfolds in 8 steps:

1. On the homepage of the game website, the instructor chooses the role of instructor by clicking on the [Instructor] button. The instructor gives a name to the game and clicks [Submit]. A unique identification number is assigned to the game. This number will appear at the top of every screen. The instructor projects his computer screen on a big screen for everyone to see. The Instructor View contains the information on the status and history of the game, as well as the controls to move the game from day to day, and to introduce a toll on the freeway. (See the Screen Captures section below.)

2. The instructor informs the students that the winner of the game will be the player with the smallest average travel cost. The instructor communicates the name and number of the game to the students, and invites them to join the game.

3. The students join the game created for them by the instructor. Note that students can only connect to a game after the instructor has created it. Before playing the game, the students are given instructions to read. They should read the instructions carefully before proceeding to the game.

4. The students make their move for the day by choosing whether to get on the freeway or take the back roads. Once submitted, the student's choice cannot be undone. At any time, students can click on the [Toggle] button at the bottom of their screen to open/close their history of play.

5. After all the students have played, the instructor moves the game to the next day. (The Instructor View includes a dynamic counter of the number of players that have played.) Moving the game to the next day does not require that all players have played. However, if a player has missed a day, he cannot go back to it

later. No play will be recorded for that day. After the instructor moves to the next day, the students' screens are automatically updated after a few seconds.

6. Steps 4 and 5 are repeated 15 times or more. (The actual number of days played is up to the instructor but we recommend 15 at least). At that point the instructor introduces the toll by clicking on [Activate toll]. **Activating the toll automatically moves the game to the next day. For this reason, the toll should be activated only after all players have played**.

7. The game continues with the toll in place. It is played for the same number of days as the previous stage (i.e., when there was no toll).

8. When the instructor is ready to stop the game, he or she should print a copy of the Instructor View, and then click on [Quit the game]. At this point, the system will display the list of players in decreasing order of average travel costs. The winner will appear at the top.

BEHIND THE SCENES: GAME PARAMETERS AND EQUILIBRIUM ANALYSIS

As previously mentioned, the travel time on the back roads is always thirty minutes. To model the freeway we assume that the time spent in traffic goes up in a convex non-linear way with utilization of the freeway (i.e., with the fraction of drivers choosing that route, see Figure 1), somewhat similar to the manner in which waiting time in a queueing system goes up non-linearly with utilization of the resource. Specifically, we assume the time spent on the freeway (in minutes) is given by:

$$\mathrm{T} = 15 / (1 - \tfrac{2}{3}\,\mathrm{F}) \qquad (1)$$

where F represents the fraction of players on the freeway. When no one is on the freeway, F = 0 and T = 15 minutes. When everyone chooses the freeway, F = 1 and T = 45 minutes. Valued are $20 per hour, these travel times correspond to $5 and $15 respectively. (By comparison, the travel cost on the back roads is always $10.) Consistent with the notion of an externality, each commuter who joins the freeway increases the travel time for everybody else.

We now analyze the game formally. We derive the outcome under the theoretical Nash equilibrium and compare it to the minimum possible cumulative travel time summed across all users, which we refer to as the socially-optimal outcome.

In equilibrium, since all players are identical (they all incur a charge of $20 for each hour on the freeway), all players will be indifferent between taking the freeway and the back roads. Thus, the Nash equilibrium is obtained when

$$\mathrm{T} = 15 / (1 - \tfrac{2}{3}\,\mathrm{F}) = 30 \qquad (2)$$

which implies that $F = ¾ = 75\%$. (See also Figure 1.) Note that since all players are identical, the Nash equilibrium implies that either some players self-select into always taking the freeway or always taking the back roads, or else players adopt a mixed strategy (for example, all players randomly take the freeway 75% of the time). For N players, the cumulative travel time (that is, the sum of individual travel times across all players) is:

$$30\,N\,[1 + F\,(3 - 4\,F) / (4\,F - 6)] \qquad (3)$$

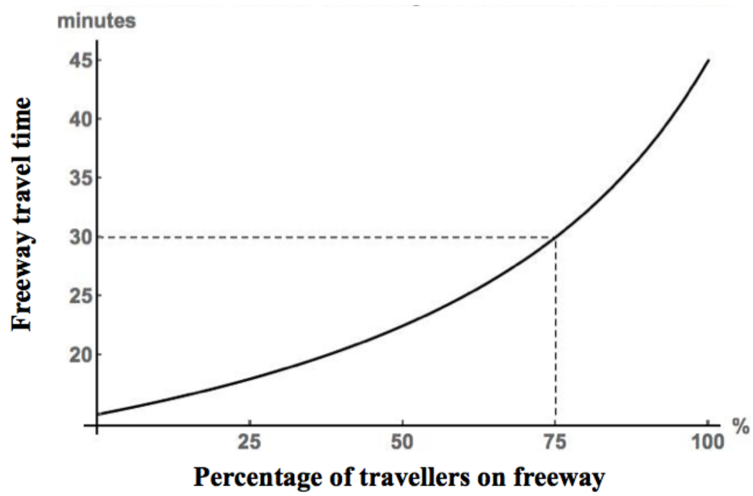


Figure 1. Freeway travel time increases non-linearly with freeway traffic [see Equation (1)].

Next consider the minimum cumulative travel time summed across all users (the socially-optimal outcome). This is obtained for $F = ¾ (2 – \sqrt{2}) \approx 43.9\%$, again implying a mixed-strategy approach. In this case, each freeway driver's travel time is $15\sqrt{2} \approx 21.2$ minutes, and the total travel time (summed across all freeway users plus all back-roads travelers) is $15\,N\,(3\sqrt{2} – 5/2) \approx 26.14\,N$. Thus, the Nash equilibrium outcome (which has a cumulative cost of 30 N) experiences an 'efficiency loss' of about 3.86 N minutes as compared to the socially-optimal outcome. The total travel time is plotted in Figure 2, where the shaded area represents an area of traffic congestion.

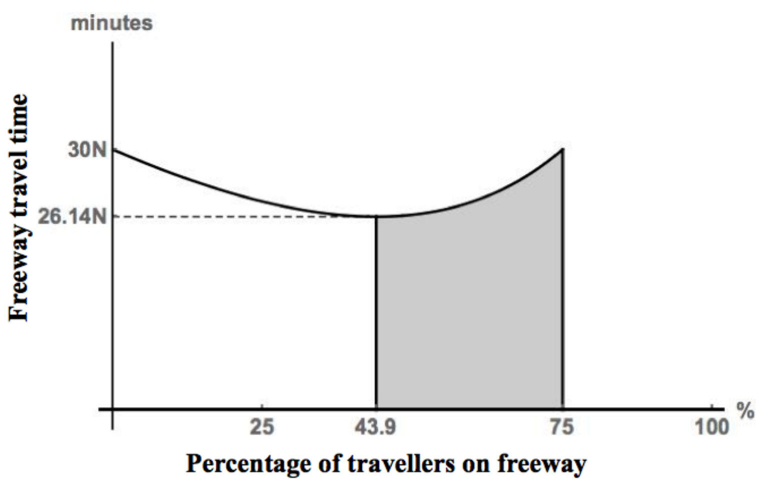


Figure 2. Cumulative travel time summed over all *N* players.

Finally, we derive the value of the toll that induces the socially-optimal outcome. After the toll is introduced, the freeway travel cost is

$$C = 5 / (1 – \tfrac{2}{3} F) + \tau \qquad (4)$$

where τ denotes the toll, and the player's time is valued at \$20 per hour. In equilibrium, C = \$10, from which we can derive the equilibrium traffic F* as a function of τ. The result of these calculations is

$$F^* = 3(5 – \tau) / 2(10 – \tau) \qquad (5)$$

We derive the toll τ^* that induces the socially-optimal traffic by setting $F^* = \frac{3}{4}(2 - \sqrt{2})$. We find that

$$\tau^* = 5(2 - \sqrt{2}) \approx 2.93 \qquad (6)$$

For simplicity, in the Freeway Game the toll is rounded to $3.

DEBRIEFING THE SIMULATION WITH STUDENTS

The learning objectives will be accomplished by students playing the game and participating in the discussion that follows.

After playing the game, the instructor rewards the winner with the prize, and asks her to discuss her strategy with the class. At this point, all students can be invited to share their strategies or any other insights from playing the game.

The following is a set of questions to support the discussion:

1. How does your objective to minimize your own time interact with the other players' objectives?

2. With hindsight, would you have done anything differently?

3. Does the game seem to have reached an equilibrium position? If so, describe the equilibrium state of the game. Using Figure 1, you can show graphically that the Nash equilibrium is when the freeway traffic is at 75%. (For the optional scenario, the Nash equilibrium is at 100%). If appropriate, you can assign the students to solve for the Nash equilibrium based on Figure 1 or equation (1). Equation (3) can be used to find the social optimum.

4. How does the status of the game compare to the optimal outcome? Recall that this is achieved when the freeway traffic is at 44%. Why is the minimum total travel time difficult to achieve?

   Recall that the expected outcomes are: (*i*) When there is no toll, the total travel time should exceed the socially-optimal outcome; (*ii*) After introducing the toll, the total travel time should be very close to the socially-optimal outcome.

5. What role does the toll play? How did the introduction of the toll impact your decisions? How did the toll impact the performance of the freeway, and of the system as a whole?

6. After explaining what the optimal number of commuters is, ask the students how they would solve the problem of congestion? A possible answer is to limit entry to the freeway to the optimal level. This would be an example of a "command-and-control" regulation. How easy would it be to enforce such a limit? Discuss with the students how the toll could be used, and how the toll fee should be determined.

General questions:

7. Can you think of other externalities that are relevant to business? List several examples of externalities, distinguishing between positive and negative externalities, then ask: How important do you think these externality-related problems are?

   In addition to discussing the causes of externalities, it is important for the instructor to debate possible solutions with the students. Some solutions fall in the realms of public policy, for example, environmental regulations; others rely on other institutional or voluntary arrangements.

It is important for the students to experience the tension that arises between their individual goal (i.e., to minimize one's own travel time), and the overall goal of minimizing the total travel time. This tension results from the externality. It should be clear that in the absence of a central planner who somehow coordinates the travelers to minimize the total travel time, it will be difficult to achieve the optimal outcome.

8. How can these problems be solved? What kinds of solutions can you think of? Apart from government regulations, how would you solve these problems?

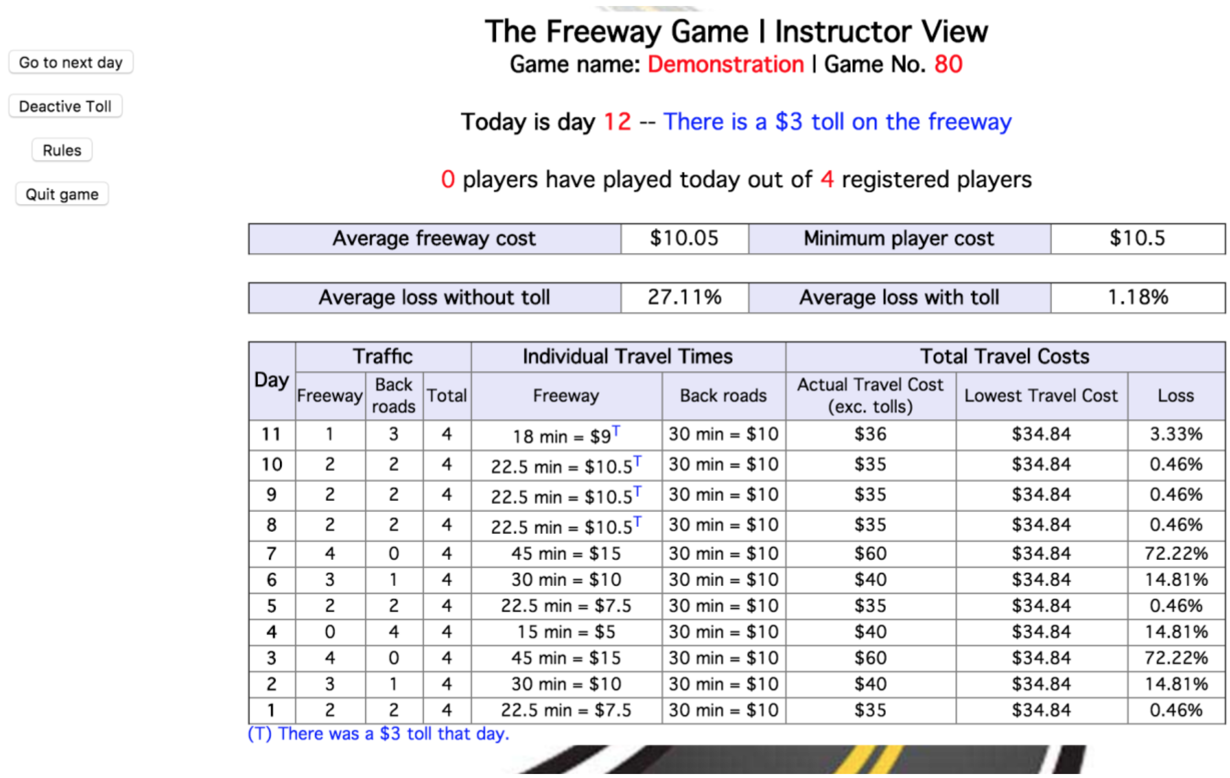
9. What do you think is the role of managers in dealing with externalities?

In our discussion of the Freeway game, we like to focus on the problem of pollution. We emphasize the need for regulations to internalize the costs of pollution, and discuss common forms of regulations: command-and-control (such as technology mandates or performance standards), emission taxes, cap-and-trade, extended producer responsibility, information programs (e.g., reporting requirements, eco-labels), and voluntary programs (e.g., Energy Star, LEED certification for buildings). See Stavins (2003) for a review of environmental regulations around the world. We then discuss how regulations impact business operations.

SCREEN CAPTURES

The two main screens of the games are the Instructor View and the Student View.

INSTRUCTOR VIEW


Go to next day

Deactive Toll

Rules

Quit game

The Freeway Game | Instructor View

Game name: Demonstration | Game No. 80

Today is day 12 -- There is a $3 toll on the freeway

0 players have played today out of 4 registered players

Average freeway cost	$10.05	Minimum player cost	$10.5

Average loss without toll	27.11%	Average loss with toll	1.18%

Day	Traffic			Individual Travel Times		Total Travel Costs		
	Freeway	Back roads	Total	Freeway	Back roads	Actual Travel Cost (exc. tolls)	Lowest Travel Cost	Loss
11	1	3	4	18 min = $9 T	30 min = $10	$36	$34.84	3.33%
10	2	2	4	22.5 min = $10.5 T	30 min = $10	$35	$34.84	0.46%
9	2	2	4	22.5 min = $10.5 T	30 min = $10	$35	$34.84	0.46%
8	2	2	4	22.5 min = $10.5 T	30 min = $10	$35	$34.84	0.46%
7	4	0	4	45 min = $15	30 min = $10	$60	$34.84	72.22%
6	3	1	4	30 min = $10	30 min = $10	$40	$34.84	14.81%
5	2	2	4	22.5 min = $7.5	30 min = $10	$35	$34.84	0.46%
4	0	4	4	15 min = $5	30 min = $10	$40	$34.84	14.81%
3	4	0	4	45 min = $15	30 min = $10	$60	$34.84	72.22%
2	3	1	4	30 min = $10	30 min = $10	$40	$34.84	14.81%
1	2	2	4	22.5 min = $7.5	30 min = $10	$35	$34.84	0.46%

(T) There was a $3 toll that day.

Figure 3. Instructor View.

Figure 3: The number of registered players is calculated automatically. Likewise, the number of players who have played today is also calculated automatically and refreshed every 3 seconds or so. These two indicators help the instructor know when all players have played, and it is time for the instructor to move the game to the next day. This is done using the [Go to next day] button.

The toll is introduced and removed with the toggle button [Activate toll] [Deactivate toll]. **Activating or deactivating the toll will move the game to the next day. For this reason, it should be done only after all players have played.**

At the end of the game, the instructor can use the ‘Total Travel Costs’ columns to show to the students that the actual travel cost is higher than the lowest possible travel cost (which we described previously as the social optimum). The loss column calculates how much time is wasted by the system compared to the lowest possible travel cost. The formula is 100 * (Actual Travel Cost – Lowest Travel Cost) / Lowest Travel Cost.

Summary statistics are presented at the top of the screen. The average freeway cost should, in general, be close to the backroad travel cost of $10. The minimum player cost is the average travel cost of the current winner of the game. The data on average loss with or without the toll show the effectiveness of the toll in bringing the game close to the social optimum. At the social optimum, the loss is 0%.

STUDENT VIEW

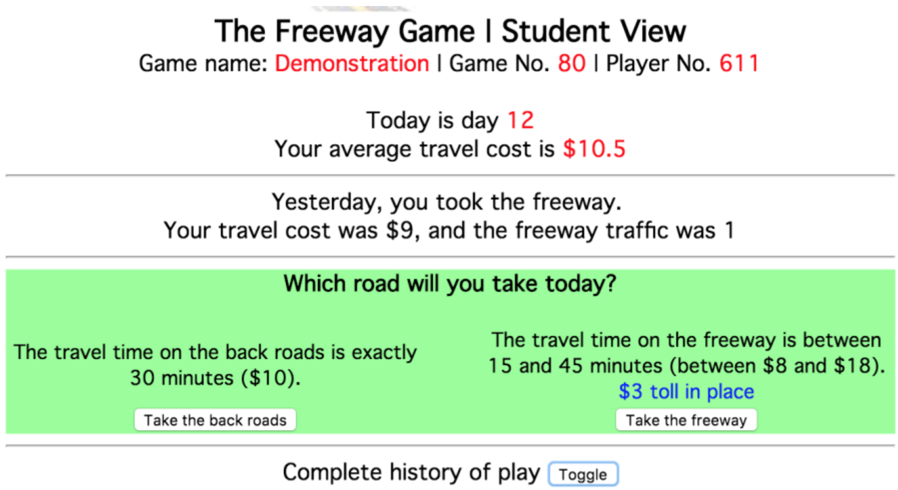


Figure 4. Student View at the beginning of a new day.

Figure 4: At the beginning of each day, the students are faced with a choice: Take the back roads [Option on the left] or take the freeway [Option on the right].

The [Toggle] button at the bottom of the screen is to display the complete history of play of the player. It is not visible by default. (See Figure 6 for a screen shot with the history of play.)

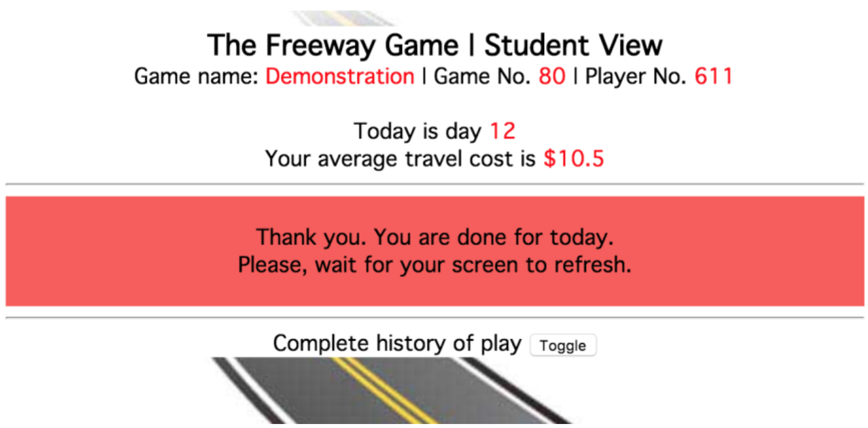
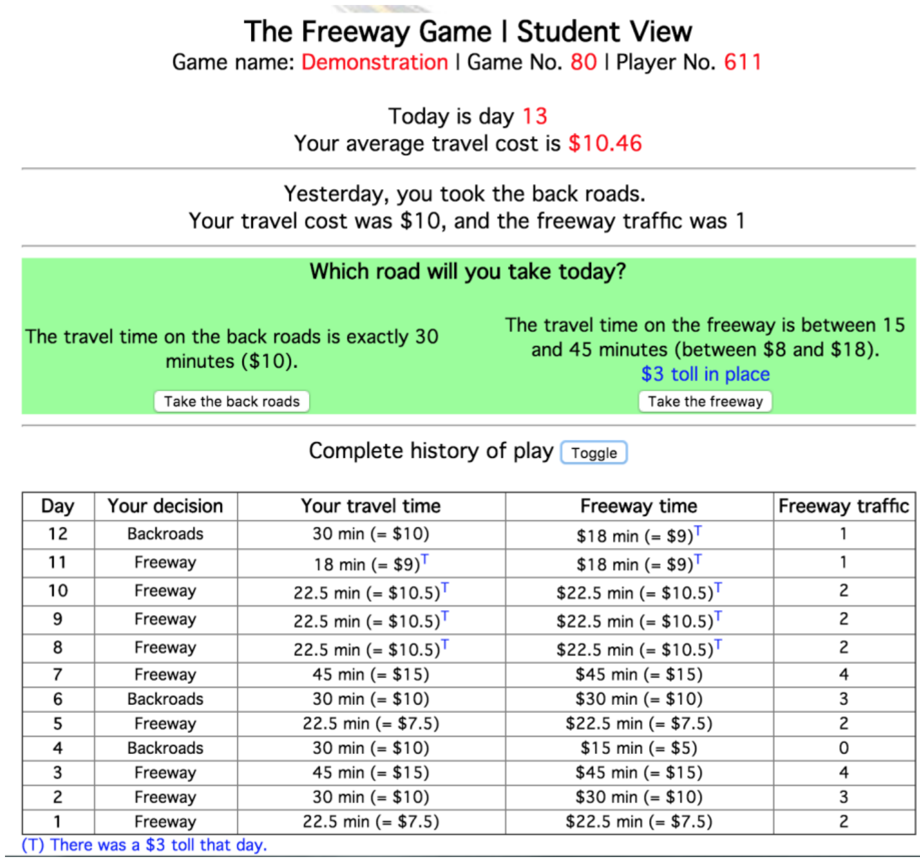


Figure 5. Student View after the player's decision is recorded.

Figure 5: After the students input their decision for the current day, they have to wait for the instructor to move the game to the next day. The Student View is automatically refreshed. There is no action on the part of the students at this point.



The Freeway Game | Student View

Game name: Demonstration | Game No. 80 | Player No. 611

Today is day 13

Your average travel cost is $10.46

Yesterday, you took the back roads.

Your travel cost was $10, and the freeway traffic was 1

Which road will you take today?

The travel time on the back roads is exactly 30 minutes ($10).

Take the back roads

The travel time on the freeway is between 15 and 45 minutes (between $8 and $18).

$3 toll in place

Take the freeway

Complete history of play Toggle

Day	Your decision	Your travel time	Freeway time	Freeway traffic
12	Backroads	30 min (= $10)	$18 min (= $9)T	1
11	Freeway	18 min (= $9)T	$18 min (= $9)T	1
10	Freeway	22.5 min (= $10.5)T	$22.5 min (= $10.5)T	2
9	Freeway	22.5 min (= $10.5)T	$22.5 min (= $10.5)T	2
8	Freeway	22.5 min (= $10.5)T	$22.5 min (= $10.5)T	2
7	Freeway	45 min (= $15)	$45 min (= $15)	4
6	Backroads	30 min (= $10)	$30 min (= $10)	3
5	Freeway	22.5 min (= $7.5)	$22.5 min (= $7.5)	2
4	Backroads	30 min (= $10)	$15 min (= $5)	0
3	Freeway	45 min (= $15)	$45 min (= $15)	4
2	Freeway	30 min (= $10)	$30 min (= $10)	3
1	Freeway	22.5 min (= $7.5)	$22.5 min (= $7.5)	2

(T) There was a $3 toll that day.

Figure 6. Student View with history of play.

COMPLEMENTARY RESOURCES

In this section, we provide several teaching resources that can be used in connection with the Freeway Game. They consists of videos, readings and quizzes related to externalities and online games:

YouTube videos that conceptually introduce externalities using graphical, production—consumption models:

- Negative externalities: https://www.youtube.com/watch?v=nBw6KvU51BE
- Positive externalities: https://www.youtube.com/watch?v=TSTLLFJbaA4
- The role of Pigovian taxes to correct externalities: https://www.youtube.com/watch?v=UYShebe44Xs
- Tragedy of the Commons: https://www.youtube.com/watch?v=0b2Tl0x-niw

To understand the different types of externalities

- Naughton, H. (2013). A note on teaching externalities: Distinguishing between consumption and production externalities. *International Review of Economics Education*, *14*, 94-99.

For students to review and test their knowledge of externalities and environmental policy:

- http://quizlet.com/14442585/externalities-environmental-policy-and-public-goods-flash-cards/

For an introduction to market-based regulations for pollution control (Chapter 5 defines externalities, and makes a connection with two related problems, namely the public good problem and the tragedy of the commons. It also uses traffic congestion as an example of negative externality, similar to what we do in the game):

- Keohane, N. O., & Olmstead, S. M. (2007). *Markets and the Environment*. Washington: Island Press.

For a review of market-based environmental policy instruments used throughout the world

- Stavins, R. N. (2003). Experience with market-based environmental policy instruments. *Handbook of environmental economics*, *1*, 355-435.

For ideas on how to use the Freeway Game to extend business education beyond the tools and mechanics of business to include liberal learning:

- Giraud-Carrier, F. C., & Schmidt, G. M. (2015). Learning in the Fast Lane: The Freeway Game. *Decision Sciences Journal of Innovative Education*, *13*(3), 273-287.

For a discussion of environmental externalities and their impact on supply chains:

- Sroufe, R. and Melnyk, S. (2013). *Developing Sustainable Supply Chains to Drive Value: Management Issues, Concepts and Tools.* Business Expert Press.

For a taxonomy of online games used for business education

- Wood, S. C. (2007). Online games to teach operations. *INFORMS Transactions on Education*, *8*(1), 3-9.