



# Civil Engineering

**TRANSPORTATION RESOURCES**  
**module**

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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# Introduction

Engineers design and maintain systems that allow people, vehicles, and goods to travel in the safest and most efficient ways possible. Think of a way to travel, and it's likely that an engineer has had a hand in it, from roadways, highways, or bridges, to mass transit systems and railways, to airports and seaports.

Like all engineers, transportation designers are problem-solvers. When trying to find the best solution for any transportation problem, engineers must take into account community concerns, project costs, client needs, construction materials, sustainability issues, state and federal mandates, and a host of other variables. No matter the tradeoffs, public safety is the top priority.

This module introduces students to transportation engineering issues related to their lives. In the first activity club members will plan a new road based on a combination of factors, second activity, students consider the function of streets in their own community and design what's known as a "complete street" that serves multiple users. In the third and fourth activities, students observe traffic patterns at a local intersection and learn how to design a left-hand turn lane to optimize traffic flow. In activity four, students take a step back to better understand how a construction project is staged and identify professionals with whom civil engineers might collaborate. And in the final activity, students dig into earthworks by building and testing small-scale, reinforced retaining walls.



## Activities Overview

### ① We Need a Road (1 meeting)

- Students first lay out a route between a city and new education center that is analyzed on the basis of cost alone. Students then revisit their design and plan a road based on an expanded set of criteria.

### ② A Street for Everyone (2 meetings)

- Part 1: Students describe users and uses of some local streets, and then classify streets in their city.
- Part 2: Students use the web-based Streetmix app to redesign a local street into a Complete Street.

- **Learning Objectives**

Students will be able to:

- List characteristics and users of streets.
- Understand how streets are classified.
- Explain what a Complete Street is.
- Develop a road section of a Complete Street.

### ③ Counting Cars (2 meetings)

- Part 1: Students conduct a traffic count at a busy local intersection with a traffic light (signalized) but without a dedicated left-turn lane.
- Part 2: Students analyze the data, evaluate the intersection's capacity and level of service, and apply a growth rate to the traffic data.

- **Learning Objectives**

Students will be able to:

- Describe what traffic counts and turning movements are and why they are important to collect.
- Determine how different parts of an intersection function.
- Construct a turning movement diagram with field data from a local intersection.
- Describe the concept of level of service and how it impacts transportation engineering.
- Apply a growth rate to current traffic data to project a design forecast.
- Decide if the intersection studied may need improvements now or in the future.

#### ④ It's Your Turn (2 meetings)

- Part 1: Students learn some of the design considerations that factor into street planning and design.
- Part 2: Students use data adapted from a real-world project to design a dedicated left-turn lane for an existing roadway.

- **Learning Objectives**

Students will be able to:

- Describe what a dedicated left-turn lane is.
- List the benefits of a dedicated left-turn lane.
- Understand design considerations for creating a left-turn lane.
- Design a dedicated left-turn lane.

#### ⑤ Retaining Wall Challenge (1 meeting)

- Students use two boxes as platforms to build and test small-scale retaining walls, each employing a different soil reinforcement strategy. Final walls are subjected to increasing loads until they collapse.

- **Learning Objectives**

Students will be able to:

- Explain the function of a retaining wall.
- Describe how a mechanically reinforced wall is constructed.
- Recognize the lateral stresses that are caused by an applied vertical force.
- Describe the forces acting against a wall.
- Understand that reinforcing soil strengthens it.



### Planning Tips

- **Choose and plan activities.** Work with your faculty advisor and other engineer volunteers to decide which activities you'd like to do with your students and in what order. Feel free to modify activities or add other activities to match your students' interests.
- **Decide if you will be including a speaker, field trip, or community service project.** The Make It Real, Make a Difference section (p. 60) suggests real-world experiences that are related to transportation engineering. Be sure to arrange these activities several weeks before you begin the module. For more planning and organizing ideas, see the Getting Started section of this guide.
- **Gather materials ahead of time.** See the Master Materials List in the following section for a summary of the materials used in this module. Work with your faculty advisor to determine requirements (such as consent forms) needed for field trips or student surveys.
- **Recruit volunteers.** It's helpful to have an adult overseeing one, or at most two, teams when students are doing their traffic counts (Activity 3: Counting Cars) fieldwork. Recruit plenty of engineer mentors to assist you during this activity.



## Master Materials List

This chart summarizes the materials used in this module. For items and quantities needed for each meeting, see the meeting Leader notes in each activity.

Meeting	Material	Quantity for 10 students	Source
<b>Activity 1: We Need a Road</b>	15-inch pieces of string	12.5 feet	borrow from home
	Rulers	10	borrow from home or school
	Pencils with erasers	10	borrow from school
	Small prizes (candy)	1 bag	grocery store
<b>Activity 2: A Street for Everyone</b>	Older map of your city (optional)	for leader use	city planning office
	Map of a portion of your city	for leader use	local map scanned in, or Google maps or Google Earth
	Screen grabs of street views of about 10 streets from city map	for leader use	Google maps
	Photos of 2 or 3 mixed-use local streets	for leader use	take and scan in photos, or use photos from Google maps Street View option
	Plans for the street that students choose to redesign	for leader use	either from the city planner or by using Google's Street View and map scale information
	Presentation equipment	for leader use	borrow from school
<b>Activity 3: Counting Cars</b>	Close-up of the intersection to be studied	4	Google maps
	Stopwatch or watch	4 for adult volunteers	borrow from home or school
	Clipboards (or other writing surface)	10	borrow from home or school
	Pencils with erasers	10	borrow from school
	Safety vests meeting current standards	10 + 4 for adult volunteers	borrow from school or city planning dept.
	Clicker counters (optional)	10	borrow from city planning dept.
	Calculator	10	borrow from school
	Presentation equipment	for leader use	borrow from school

Meeting	Material	Quantity for 10 students	Source
<b>Activity 4: It's Your Turn</b>	Acetate markers in red, green, and blue	for leader use	borrow from school or office supply store
	1 engineering scale	3–4	office supply store or ASCE engineering scale
	1 12-inch 30- to 60-degree triangle	3–4	borrow from school
	1 12-inch 45-degree triangle	3–4	borrow from school
	Red pencils with erasers	10	borrow from school
	Calculators	3–4	borrow from home or school
	Scissors	3–4	borrow from school
	Clear tape	3-4 dispensers	borrow from school
	Presentation equipment	for leader use	borrow from school
<b>Activity 5: Retaining Wall Challenge</b>	Dry sand	50–200 pounds depending on the club size	home improvement store
	Shovel	1	borrow from home
	Hand scoop, such as a large plastic cup	3–4	borrow from home
	5-gallon bucket	3–4	home improvement store
	Scissors	3–4	borrow from home or school
	5- to-10-pound stackable weights, such as bricks	up to 150 pounds if possible	home improvement store
	wood boxes with removable bulkhead (see activity for materials to build) OR Really Useful Box® 8-Liter with hinged front (plastic)	6-8 (2 per team)	plastic box available from Office Depot Stock #452279

Meeting	Material	Quantity for 10 students	Source
if using wood box:	10-inch x 10-inch paper sheets	3-4	borrow from school (cut down to listed dimensions from larger size)
	11-inch x 14-inch paper sheets	3-4	borrow from school or home
	Masking tape	1-2 rolls	borrow from school
	Toilet paper	1 roll	borrow from home
using plastic box:	8.5-inch x 6.0-inch paper sheets	3-4	borrow from school (cut down to listed dimensions from larger size)
	8.5-inch x 11.0-inch paper sheets	3-4	borrow from school or home
	Masking tape	1 roll	borrow from home or school
	Toilet paper	1 roll	borrow from home

# Activity 1: We Need a Road (1 meeting)

## The Challenge:

Determine the most optimal route between a town and a new education center.

**Time: 1 meeting**

**Overview:** Students first lay out a route between a city and new education center that is analyzed on the basis of cost alone. Students then revisit their design and plan a road based on an expanded set of criteria.

## Learning Objectives:

Students will be able to:

- Describe some of the factors engineers must consider during project planning.
- Consider and evaluate multiple criteria.
- Recognize that no design can meet everyone's need but the most optimal design will be the best one given the circumstances.
- Understand that sustainability plays a role in transportation engineering.

## Preparation:

Review the leader notes and read through the entire activity.

- **Gather materials:**
  - Copies of the "We Need a Road" student handout (1 per student)
  - Copies of the "Public Hearing" student handout (1 per team)
  - 1 15-inch pieces of string (1 per student)
  - Rulers (1 per student)
  - Pencils with erasers (1 per student)
  - Small prizes (candy)

## Activity (60 minutes)

### ① Icebreaker (5 minutes)

- Ask students to name all the different ways they are able to get around in their town. (Students may name walking; biking; driving; or riding a bus, train, or boat.) How, if at all, do any of these different ways overlap in the areas they reach? Are there some parts of the town that are only accessible by one or two ways?
- Tell students that the job of transportation engineers is to move people and goods from one place to another in an efficient and safe manner. Engineers are always thinking about the best ways to do that, whether

# The Big Idea!

There is more to designing a road than just cost.

Budgetary constraints are a driving force of any project, but they are only one of many factors that must be considered during transportation planning. Many other criteria come into play, most notably sustainability and safety. Sustainable development takes a long-term view to planning, design, and construction of any project to ensure it is completed in a cost-effective, environmentally protective, and socially responsible manner. In addition to being sustainable, it is paramount that a project is designed to be safe.

When economics are considered, it's not just the cost and maintenance of the project, but also forecasting any impact the project might have on future development and employment. In the same vein, environmental factors don't just mean additional costs to clear trees or fill in wetland for a future road, but also taking into consideration the impact cutting those trees might have on the loss of carbon sequestration or biodiversity, or what it would entail to mitigate any habitat loss. And designing for social sustainability means striving for improved community livability, human well-being, and social equity.

No one transportation solution will meet everyone's needs. But the most optimal solution will have taken into account many group's needs—as well as issues of sustainability and safety—and been arrived at through careful deliberation of options and public input.

**Video Link: Engineering Research: Sustainable Pavement (1min 26sec)**  
<http://www.youtube.com/watch?v=GblzPEKnp7w>  
See how the University of Waterloo's engineering school in Canada is working to design a long-life, sustainable pavement.

they are tackling a new problem of how to connect places, or revisiting ways to improve existing modes of transportation.

## ② Present First Design Challenge (5 minutes)

- Tell students they are going to design a road that will connect two places. Distribute the “We Need a Road” handout to each student. Tell students that they need to design a road that goes from the city to a new education center. They cannot cross any water bodies or remove any trees.
- When students have finished, pass out the string and rulers and have students measure how long their roads are. Tell students that 1 inch = 1,000 feet of roadway, and that every 1,000 feet of roadway cost \$50,000 to build. Have students calculate and report out how much their roads cost. Once they have all been reported out, let the group know that the least expensive road wins!

## ③ Introduce Second Design Challenge (10 minutes)

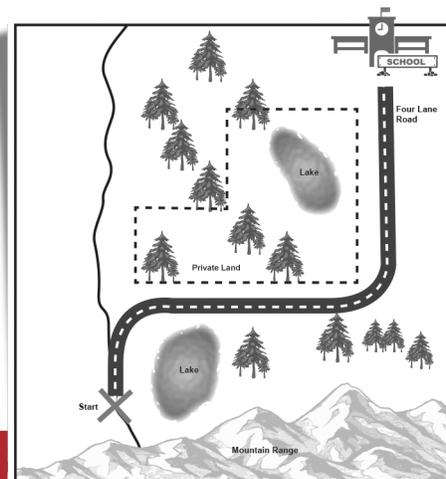
- Now let students know that designing a road is not as simple as determining the least expensive option. Inform students that engineers must take many more criteria into account when they design a roadway.
- Two of the biggest factors that engineers have to think about include sustainability and safety. Building something that is sustainable means constructing it in ways that maximize the economic benefits, minimize adversely affecting the environment, and take into account the well-being of the community. Being sustainable means taking a longer-term view toward the impacts that building a road today will have on economics, environment, and community into the future. And safety is always a top priority in anything that engineers design.
- Tell students they will be designing the same road again, but this time they will need to take additional criteria into consideration. They can now cross lakes, remove trees, or climb the mountain but each of those actions means additional costs such as planting new trees or building a bridge to cross the water.
- Organize students into teams of three to four and distribute the “Public Hearing” handout to students (this handout includes a fresh copy of the map students will be using to design their road).
- Review the new, additional criteria with students, and answer any questions students may have. Inform students that the costs in the activity do not reflect actual construction costs.
- Note to students that the new criteria they are considering are only a few of the many variables engineers must evaluate. (For example, although time is not considered here, it is often a driving factor in real-world projects.) This activity is designed to help students understand that engineers must weigh many factors when designing, and use their expertise to arrive at the best solution for each situation.

## ④ Design Road (20 minutes)

- Tell student they now have 20 minutes to design their road. Walk around and assist each team as it works on its design.

## ⑤ Share Results (15 minutes)

- Have each team present its design to the group and explain why it chose to lay out the road the way it did.
- Below is one possible design solution. Cost: \$775,000 (7.5” four-lane road = \$750,000 + \$25,000 for removing one tree. Original budget \$550,000 + developer funds of \$450,000 means a surplus of \$225,000 that goes toward improving existing schools).
- There are several acceptable solutions to this design problem. The one shown above reflects a fairly direct route, provides scenic views of the mountain range, considers future traffic needs (is four lanes), is safe in terms of horizontal alignments (design curvature only as speed was not a consideration in this activity), and provides a



number of access points for the future development. It also takes into consideration the cultural aspects of the mountain range by not going through or passing too closely to the range.

- An alternative to this design could include a bridge over the lake. This solution would provide a slightly more direct route than the one above and have the added value of providing an additional nice aesthetic (the bridge). However, the bridge would also need to be maintained over time. In order to get the developer's money (access from two sides of the property), an access road could be added that would run along part of the property on the northern side. Other designs could go around the western side of the private property and not cut down any trees at all.
- Have students critique each other's design and vote as a class which design they think is best (i.e., meets the most number of needs).

### ⑥ Wrap up (5 minutes)

- Tell students that they designed a road in a manner similar to what real engineers do. Oftentimes, engineers will come up with several alternatives during the first phase of a project (called the feasibility stage) and determine which alternative they think is best given all the circumstances. If there is time, share a real-world example of a feasibility report. This one was done for a road in Archdale, North Carolina: [http://www.hpdot.net/hpmpo/projects/Weant\\_Road\\_Feasibility\\_Study.pdf](http://www.hpdot.net/hpmpo/projects/Weant_Road_Feasibility_Study.pdf)



## Extensions

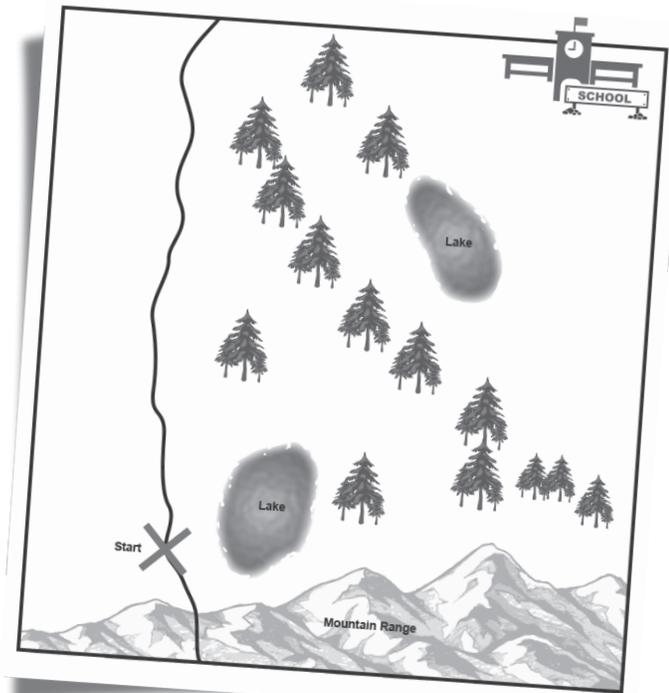
- Plan a transportation system for a new housing development. The development will include a recreational center, post office, playground, small grocery store, and theater, all which will be grouped together. Fifty houses are planned. How would you group the houses in relation to the businesses and playground? Would you include bike paths on all the roads? Provide a shuttle for houses farther out? Sketch out where the houses would go and how streets would link the houses and community center together.
- Investigate new road materials. Scientists and engineers are continually seeking ways to improve road safety, durability, and rideability. Have students research and report on some of the ways that materials scientists are working to improve roads in these areas. Information about some new technologies can be found at:
  - Solar Roadways: A Road That Pays for Itself! <http://www.go-explore-trans.org/solar-highways>
  - World's First Glow-in-the-Dark Road Promises a Brighter, More Energy-Efficient Future <http://inhabitat.com/worlds-first-glow-in-the-dark-road-promises-a-brighter-more-energy-efficient-future>
  - Illusions Slow Drivers in South Florida <http://www.betterroads.com/illusions-slow-drivers-in-south-florida>
  - How New Technology Is Changing in the Quest for Smooth Pavements <http://www.betterroads.com/smooth-going>

# We need! a Road!

Student  
handout

## DESIGN CHALLENGE 1

**Your Challenge:** A new education center has just been constructed, and a road needs to be built from the southwest corner of the town up to the front door of the new center. You cannot build across lakes or remove any trees.



## Connecting to the World

### Asphalt or Caviar?

For most transportation projects, budgets are fixed and project delays costly. But what if time were the most important factor instead of money? Well, if that were the case, you might get a road like the one built in Russia for the 2014 Winter Olympics.

The 25-mile stretch starts along the coast in Sochi and climbs to alpine venues nearly 2000 feet above sea level to the ski resort area of Krasnaya Polyana. The road was necessary since Sochi sits on the coast of the Black Sea, a less-than-ideal place for downhill snow sports.

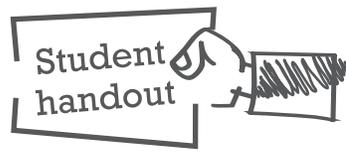
Price tag? About \$9 billion. Russian politician Boris Nemtsov had this to say about the highway: "You could have paved this road with 5 million tons of gold or caviar and the price would have been the same."

For more on how the road was built, including photos, see CNN's "Tunnels and Tarmac: How to Make the 'World's Most Expensive Road'" at: <http://edition.cnn.com/2014/02/23/sport/road-expensive-sochi-2014-winter-games>

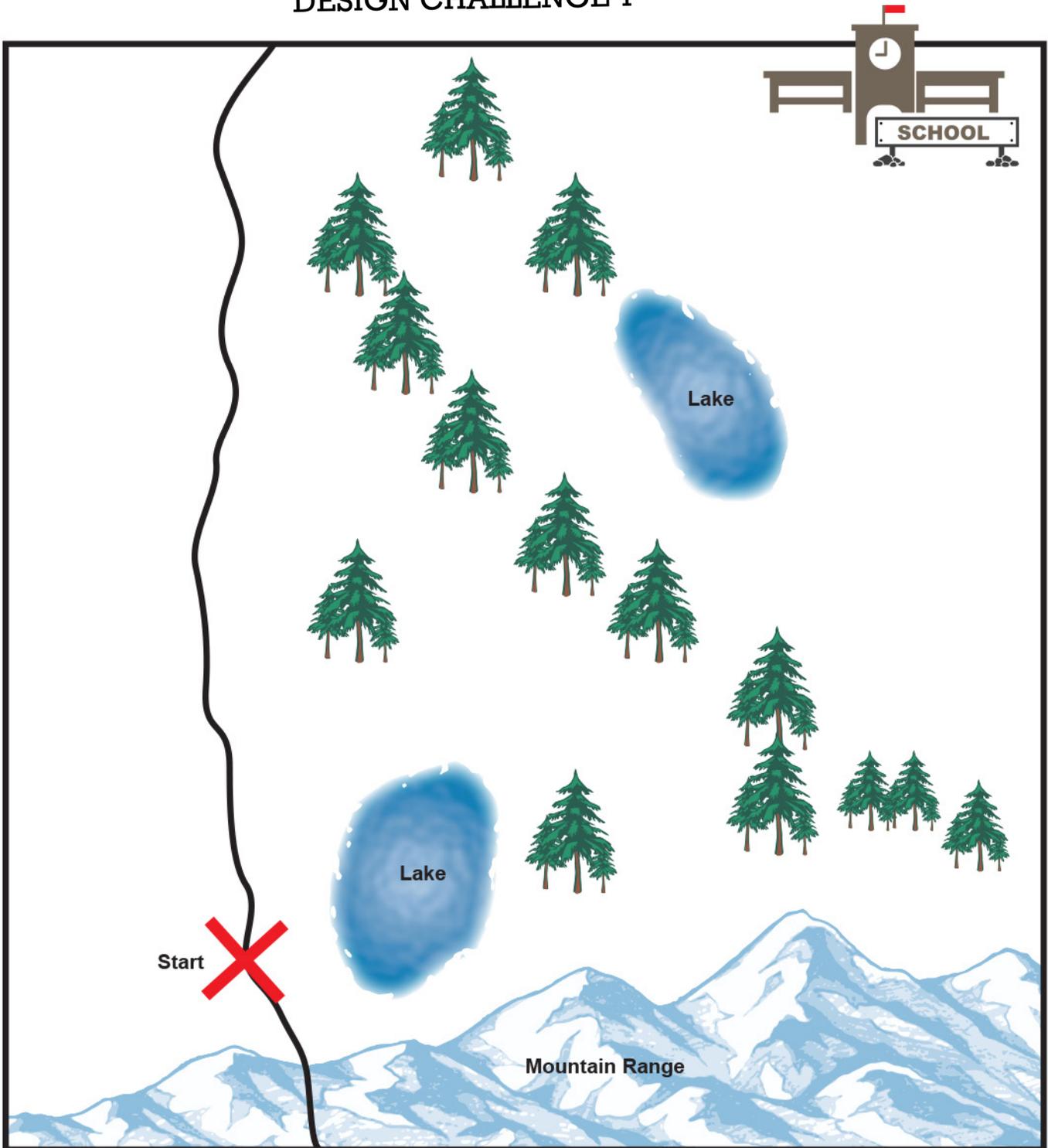


**GO CIVIL!**

# We need! a Road!



## DESIGN CHALLENGE 1



# We need! a Road!



## DESIGN CHALLENGE 2

### Public Hearing

**Your Challenge:** Your objective is to design a road for safe travel while considering sustainable design that takes into consideration economic, environmental, and social concerns. Below are the requests and reports being made by various groups at a public hearing for the road:

**Environmental Group:** This group proposed, and the town agreed, that for each tree that gets cut down, five new trees must be planted to replace it. This group would like a road be as direct as possible to reduce carbon emissions. However, this group favors a commuter rail instead of a road.

**Cultural Heritage Society:** The town's founding families originally settled in the mountain range. Remnants still exist from the 150-year-old settlement, which draw tourists during the time it is honored each year. A road would destroy the character of this historical treasure.

**Commuters:** A group of parents, educators, and others who will be using the center are proposing that the road be built along a scenic route. They are petitioning to have the road go through the mountain range, or alongside the forest edge, and/or the lakes.

**Developer:** A developer owns the private land and will not grant right-of-way to build a road through it because she is planning to construct an office park and high-end condominiums within five years. She has offered the city \$450,000 for any road that runs along all of any one side, and any part of a second side, of her property.

**City Planner:** The city planner has forecasted 10 percent growth when the office park is completed. He recommends building a four-lane road now to accommodate future traffic. He also notes that any money not spent will go toward improving current schools in the city.

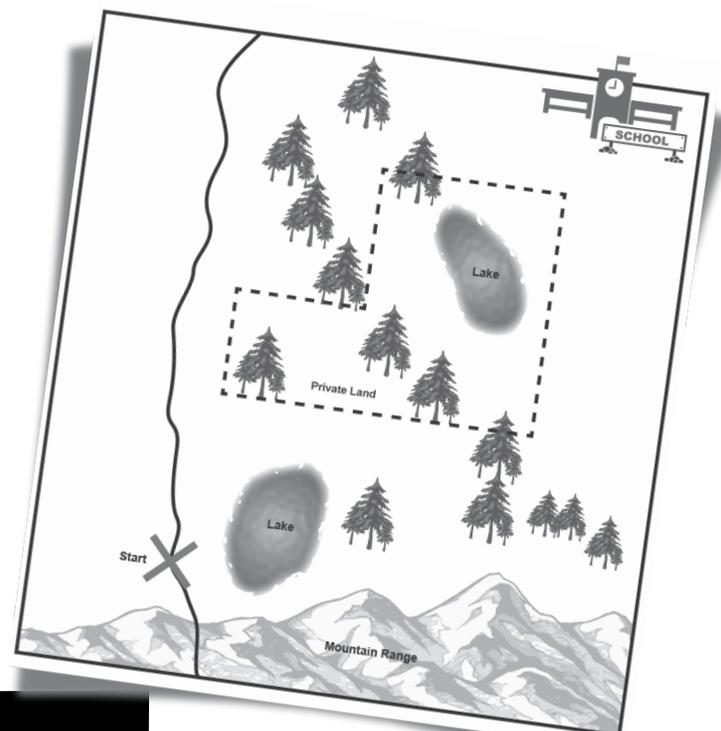
**Design Engineer:** Building a road through the mountains with the current budget is not possible. The road would be too curvy or steep to be safe. It would take four times what is budgeted to build safely through the mountain range.

### Materials:

**City Budget:** \$550,000 (additional \$450,000 available from developer if terms are met)

### Cost Sheet

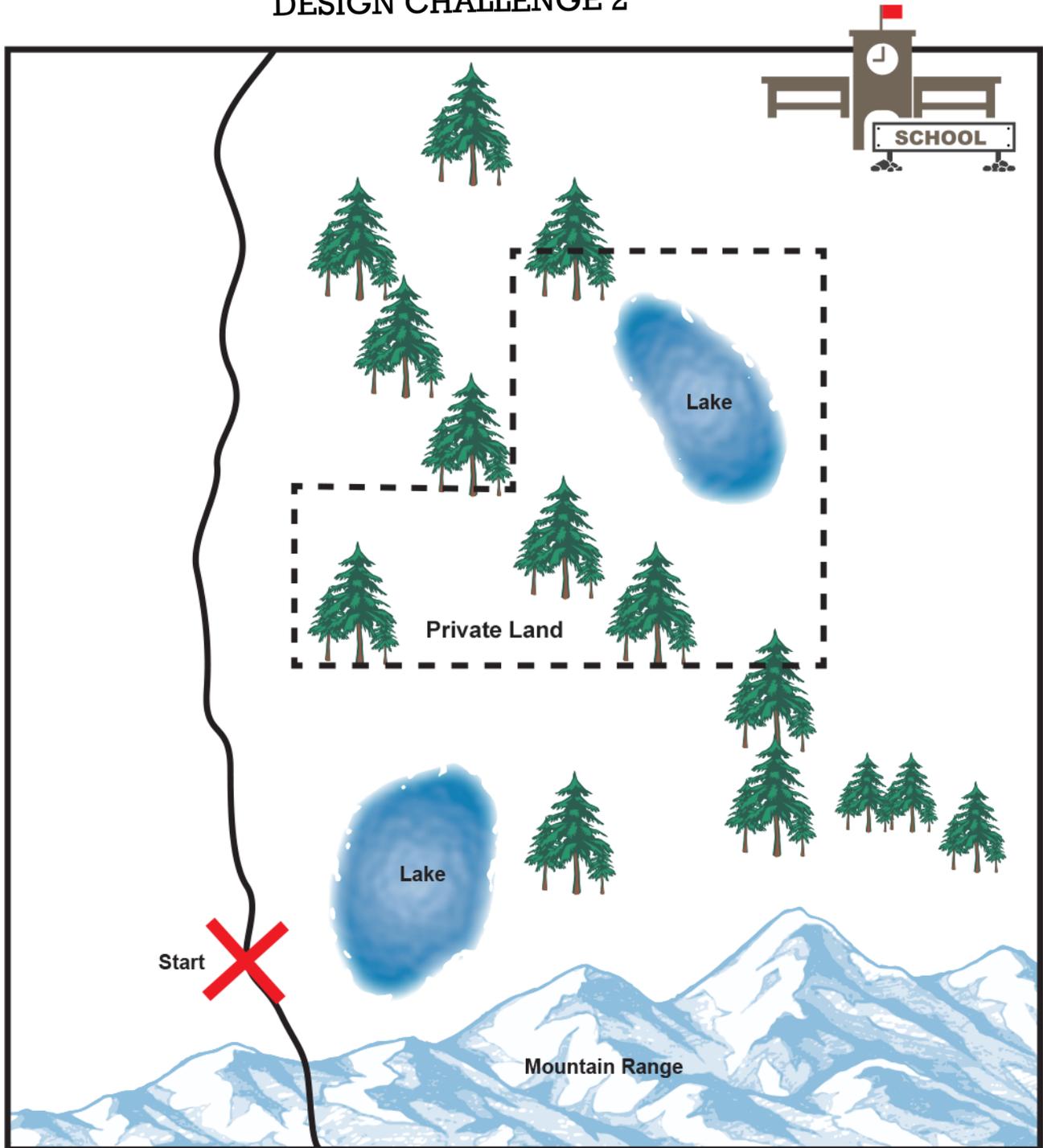
1,000 ft of 2-lane road (1 inch on map) = \$50,000  
1,000 ft of 4-lane road (1 inch on map) = \$100,000  
1 tree cut down = \$25,000  
Bridge = \$150,000  
Commuter rail = \$2,500,000



# We need! a Road!



## DESIGN CHALLENGE 2



## Activity 2: A Street for Everyone (2 meetings)

**The Challenge:** Discover how streets are classified and redesign a local street to be a Complete Street.

**Time:** 2 meetings (Note: Meeting 1 includes Part 1 and the beginning of Part 2)

**Overview:** In Part 1, students describe users and uses of some local streets, and then classify streets in their city according to the system used by the US Department of Transportation. In Part 2, students use the web-based Streetmix app to redesign a local street into a Complete Street.

### Learning Objectives:

Students will be able to:

- List characteristics and users of streets.
- Understand how streets are classified.
- Explain what a Complete Street is.
- Develop a road section of a Complete Street.

### Preparation:

- **Review the leader notes** and look at each of the websites used in the activity.
- **Gather materials**
- For Meeting 1:
  - Optional: Older map of your city and current-day map (both should show the same area for comparison).
  - Map showing just a portion of your city, scanned in from a local map or created using a tool that has an aerial view such as Google maps or the downloadable Google Earth; choose a section of the city that includes the following types of roads: local, collector, arterial.
  - Collect screen grabs of street views of about 10 of the streets above to show students.
  - Photos of 2 or 3 mixed-use local streets that include a combination of residential, commercial, cultural, or industrial uses (take and scan in photos or use a photo from Google's Street View option).
- For Meeting 2:
  - Plans for the street that students chose to redesign at the end of Meeting 1 (either from the city planner or by using Google's Street View and map scale information).
  - Create a Streetmix (streetmix.net) cross-section of the plans for the street that students chose; once the cross-section is created, copy the URL from the "Share" drop-down menu in the upper right-hand corner.

# The Big Idea!

There's more to a street than meets the eye.

At first glance, a street looks fairly straightforward: there's a road with lines for lanes and turns, signs for speed limits or parking, maybe a sidewalk. But transportation engineers have to consider much more than where to put the pavement or place the signs.

In the past, most streets were designed with people in cars seen as the most important users, and the primary goal was to move them along as efficiently and safely as possible. Any other user, such as pedestrian, bike rider, or even a bus, was seen as a hindrance. But a newer kind of street design, called a "complete street," takes into account all potential users of a roadway. Though Complete Streets are designed to be flexible, no street is perfect. Just as with a conventional street, or any other engineering project, engineers must find the optimal solution among many variables, including the number and types of users, existing or planned utilities and right-of-ways, community parking, community and sustainability concerns, and budget.



**Video Link:** Complete Streets: Community Planning 101 (2min 20sec)  
<https://www.youtube.com/watch?v=sc-GKNeclbg>  
Learn more about Complete Streets and discover the role they play in communities of all kinds.

For Meetings 1 & 2:

- Copies of the “A Street for Everyone” student handout (1 per student) (Note: make additional copies for Meeting 2 in case students don’t return with their copies).
- Presentation equipment for displaying the map, photos, and students’ Streetmix designs.
- **Preview information on Complete Streets** (Meetings 1 & 2) (see Complete Street Resources, page 21).
- **Reserve the school computer lab** or have students bring in their laptops (Meeting 2).
- **Get acquainted with the web-based Streetmix app** (read a brief overview of how the app works on page 19).



## Part:1 Street Classification (30–35 minutes)

### ① Icebreaker (5 minutes)

- Ask students to describe the street they live on. How many different types of users does it support? (e.g., pedestrians, skateboarders, bikers, drivers, bus riders) What are the main ways that people travel on the streets? What kinds of vehicles do they use? What else is on the street besides the road? (e.g., sidewalks, signs for traffic speed or parking information, utility poles, fire hydrants, landscaping). List student answers on a board or chart paper.
- Next, ask students to think about a busy street that is closest to where they live and provide the same information about it as they did about their own street.
- After students have described the characteristics of both streets have them compare how the streets are alike and how they are different.
- Inform students that engineers classify roadways by the role they play within a larger network. Each roadway is intended to help serve different travel needs and falls into one of four classifications: local, arterial, collector, and freeway. For the purposes of this activity, the focus will be on the local, arterial, and collector classifications.

### ② Introduce the Challenge (10 minutes)

- Tell students they will now be classifying streets in a portion of their city.
- Distribute the “A Street for Everyone” student handout to each student.
- Review with students the following three functional classifications (local, collector, arterial) that streets are grouped into (these are also on students’ handouts). These classifications are based on those recommended by the US Department of Transportation.
- Answer any questions students may have about the classifications (For more in-depth information about these classifications, see “Highway Functional Classification Concepts, Criteria and Procedures” at [http://www.fhwa.dot.gov/planning/processes/statewide/related/highway\\_functional\\_classifications](http://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications)).

Functional System	Services Provided
Arterial	Provides the highest level of service at the greatest speed for the longest uninterrupted distance, with some degree of access control. Specific characteristics: not meant to provide access to residential properties; 30–50 mph speed limit, 4–10 lanes wide; usually use traffic signals.
Collector	Provides a less highly developed level of service at a lower speed for shorter distances by collecting traffic from local roads and connecting them with arterials. Specific characteristics: 20–35 mph speed limit; 2–4 lanes wide.
Local	Consists of all roads not defined as arterials or collectors; primarily provides access to land with little or no through movement.

Source: Flexibility in Highway Design: Chapter 3: Functional Classification

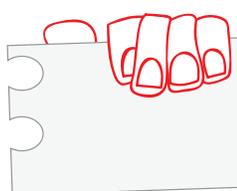
<http://www.fhwa.dot.gov/environment/publications/flexibility/ch03.cfm>

### ③ Classify the Streets (10–15 minutes)

- If you have obtained an older and current-day map of the city, show them first to give students a sense of how roadway development has changed over the city's history. Going back and forth between the maps, ask students: How have the road networks changed? Where does it seem like the most development occurred? What might have been some factors that drove where roads were developed?
- Next, project the present-day map you chose of a portion of the city on a screen, and go through each of the photos you collected of streets shown on the map. Have students classify the nature of each street. Students may struggle with some of the classifications as a street may seem like it serves as more than one type. Have students choose the functional classification that seems to most closely match the road type.

### ④ Wrap Up (5 minutes)

- After the streets are classified discuss the results with students. Did students agree with each other's assessments? Do students think that classifications could change over time if the community grew and changes were made to the road? (A roadway can deviate from its classification over time; if it does, the Federal Highway Association recommends that the road's assignment be adjusted during the functional classification review process.) What, if any, patterns do students notice about how the streets are laid out?



## Part2: Design a Complete Street (20–25 minutes)

### ① Icebreaker (5 minutes)

- Return to the list students made at the beginning of Part 1 of the activity. Ask students to fill it out with additional types of users and vehicles that might use streets. Then have students brainstorm additional items that get placed within streets.
- Show the photos of the two or three mixed-use streets you chose for the activity and ask students to identify the types of users and vehicles they serve. List students' answers on the board or presentation paper.

### ② Introduce Complete Streets (10–15 minutes)

- Currently, many streets are lacking in amenities that would increase safety for non-vehicular traffic: few

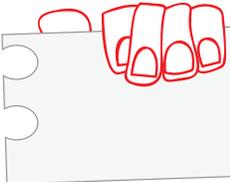
sidewalks or crosswalks, narrow vehicle lanes that crowd bicyclists, poorly designed transit stops, and in particular, limited accommodations for people with disabilities.

- Inform students that communities are beginning to move toward designing new (or improving existing) streets to accommodate more users and increase connectivity among residents and the services they use. These new types of streets are known as Complete Streets.
- Acquaint students with the following key concepts of Complete Streets:
  - Complete Streets are intended to equally consider the safe passage of all users. A Complete Street may be the destination of some users; for others, it will be where they begin or pass-through on their journey elsewhere.
  - Complete Streets are meant to be comprehensive and connected networks that disperse traffic over an interconnected system rather than funneling traffic into a single arterial road. This cuts down on the need for multi-lane arterial roads that often don't provide safe passage to bicyclists and pedestrians.
  - A Complete Street may include wider sidewalks, shared-use paths, bike lanes, designated bus lanes, accessible public transportation stops, frequent and safe crossing opportunities, better signage, light-crossing timing adjusted to provide extra time for pedestrians, median islands, curb extensions, roundabouts, and more.
- Emphasize to students that while there are general guiding principles for what a Complete Street is, there is no one-size-fits-all for a Complete Street. Each one is unique and responds to the needs of its community.

### ③ Present the Challenge (5 minutes)

- Tell students that at the next meeting they will be working in teams to use the web-based Streetmix app to redesign an existing street in their city or town to be a Complete Street that ensures safe mobility for all travelers.
- Work with students to choose a street in their city that they would like to redesign into a Complete Street. If students don't immediately agree, put it to a vote to choose the street.
- Provide students with the Streetmix app URL ([streetmix.net](http://streetmix.net)). Ask students to familiarize themselves with the web-based app prior to the next meeting.
- Ask students to bring back their "A Street for Everyone" handouts to the next meeting.
- Leader Note: Prior to the next meeting, you will need to acquire plans for the street that the students chose to redesign and create a Streetmix ([streetmix.net](http://streetmix.net)) cross-section of the plans for students. (Once the cross-section is created, copy the URL from the "Share" drop-down menu in the upper right-hand corner.)





## Part 2 (continued): Design a Complete Street (50–60 minutes)

### ④ Review the Challenge (5 minutes)

- Assign students to teams of two or three. Revisit the challenge with students and answer any questions they may have.
- Provide a copy of the “A Street for Everyone” handout to students who did not return with theirs, or for students who may have missed the previous meeting.

### ⑤ Introduce the Streetmix App (10–15 minutes)

- Project the web-based Streetmix app so that everyone can see it. Tell students that the Streetmix app is an interactive street section builder that helps community members mockup the streets they’d like to live on, and offer these mockups as future plans for city officials and planners (see Connecting to the Real World: Streetmixing for Real for examples). The Streetmix app allows users to create, save, and share cross-section diagrams in a browser. It was developed by Code for America, a nonprofit organization that helps residents and governments harness technology to solve community problems.
- Provide a brief overview of how the app works:
  - the app offers a number of different street features that can be used in the design, including buildings, sidewalks, turn lanes, planting strips, drive lanes, bus lanes, bike lanes, parking lanes, wayfinding signs, and benches.
  - upon rollover, each feature reveals customization options (e.g., a building could be a wide building, a narrow building, a residential home, a parking lot, and more; a sidewalk can be planned for dense, normal, or sparse traffic), as well as the option to increase or decrease the size of the feature.
  - features can be moved by dragging them from one place and dropping them to another, or removed altogether.
  - the app provides standard minimum and maximum sizes for each feature, and posts a notification in red alerting designers to potential issues, such as a segment being too wide or too narrow.
  - streets can be shared by copying the bookmark listed under the “Share” menu on the top far-right of the website, or if you have a Twitter account, you can sign in with your Twitter login and save a gallery of streets.
- keyboard shortcuts include:
  - use the Backspace (or Delete) key to remove a segment you’re pointing at (Shift + Backspace removes all street features).
  - use + or - keys to change a width of a segment you’re pointing at (holding Shift increases the precision of the change).

### ⑥ Design Street Section (20 minutes)

- Provide students with the URL from the street cross-section you created on Streetmix prior to the start of Meeting 2.
- Next, challenge students to redesign the street to be a Complete Street that ensures safe mobility for all travelers. Students will need to consider what may happen if they reduce or remove a travel lane to make room for another feature such as a bike lane or sidewalk.
- Allow teams 20 minutes to design their Complete Street cross-section.

### ⑦ Share Results (10–15 minutes)

- Have each group share the URL of its design with you so that you can load it onto your computer to display for the group (to find the URL, students should go to the “Share” menu on the upper right-hand side of the site;

a dropdown menu shows way to share, including the URL of the street they have created).

- Display each team's plan to the entire group and have each team present its Complete Street and explain why they chose to design it in the way they did.
- After all teams have presented, discuss how teams' plans were similar and different. What were some of the tradeoffs that teams faced when designing their streets? Which street presented seemed the most optimal in terms of meeting as many street users' needs as possible in a safe manner?

### ⑧ Wrap Up (5 minutes)

- According to the National Complete Streets Coalition, as of 2014 more than 600 regional and local jurisdictions, 27 states, the Commonwealth of Puerto Rico, and the District of Columbia have adopted (or committed to adopting) Complete Street policies. Brainstorm with students which aspects of Complete Streets might be relatively easy and low-cost to implement (marginal cost solutions could include changing light timing to accommodate slower moving pedestrians, widening sidewalks or extending curbs during drainage or sanitary sewer projects, or re-striping a road to add bicycle lanes or revise lane widths while roads are being repaved). What, if any, low-cost Complete Street features do students think may be implementable in their community?



## Extensions

- Design additional Complete Streets. Have student use Google maps to get existing street sections and design other Complete Streets. Go to Google maps (<https://maps.google.com>). Type in your city and state name. When the map comes up, choose an area with a street you're interested in. Zoom in using the "+" symbol in the bottom right corner. In this view, you can use the scale information in the bottom right-hand corner to determine the street width. Then switch to Street View by clicking on the small person icon. This view will allow you to see what utilities, sidewalks, bus stops, and other features currently exist on the street. You can rotate the view using the arrows in the round circle on the right-hand side of the page.
- Redesign street layouts in neighborhoods near city centers. Have students choose a section of the city to redesign in a way that will produce an interconnected system that allows safe and comfortable passage to common destinations for shopping and dining.
- Visit a Complete Street. Organize an outing for students to visit Complete Streets, both ones that have been converted from existing roads as well as Complete Streets designed from scratch. Talk to a representative in your city's planning office for recommendations of which streets would serve as the best examples of each of these.
- Learn about your city's plans for Complete Streets. Invite a guest speaker from the local planning department to discuss the city's processes for street design (or redesign) and whether the city is moving toward designing

# Complete Street Resources

## ARTICLES AND REPORTS

### **Street Design: Part 1—Complete Streets**

<http://www.fhwa.dot.gov/publications/publicroads/10julaug/03.cfm>

This article from a Federal Highway Administration publication reviews how Complete Streets policies can help make transportation more accessible to all travelers.

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### **The Best Complete Streets Policies of 2013**

<http://www.smartgrowthamerica.org/complete-streets-2013-analysis>

A report on the best 15 Complete Street policies of 2013, as scored by the National Complete Streets Coalition. Includes links to each policy in the Executive Summary PDF.

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### **Complete Streets Policy Adoption**

<http://www.smartgrowthamerica.org/documents/cs/policy/cs-chart-allpolicies.pdf>

The National Complete Street Coalition's regularly updated list of cities and states that have adopted Complete Streets policy, including information on the type of approved policy. Local resources may also be available; contact your city planner or search the city website for information.

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### **National Complete Streets Coalition: Resources**

<http://www.smartgrowthamerica.org/complete-streets/complete-streets-fundamentals/resources>

Provides resources on Complete Streets, including basic information, reports and articles, presentations, fact sheets, and design guidance. The National Complete Streets Coalition is a program of Smart Growth America, and organization that "advocates for people who want to live and work in great neighborhoods."

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## VIDEOS

### **Complete Streets** (4min 11sec)

<https://www.youtube.com/watch?v=RXcDFeKsMAk>

Discover how the idea for Complete Streets evolved and learn more about them in video about one community's efforts to create Complete Streets. Produced by the City of Charlotte, NC.

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### **Complete Streets: Community Planning 101** (2min 20sec)

<https://www.youtube.com/watch?v=sc-GKNeclbg>

Learn more about Complete Streets and discover the role they play in communities of all kinds.

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### **Complete Streets: Bright Side 3** (3min 57sec)

<https://www.youtube.com/watch?v=L2A49-XbQD4>

Watch this segment from The Bright Side Television to learn how communities have implemented Complete Street policies in various parts of Michigan.

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### **Complete Streets: It's About More Than Bike Lanes** (11min 2sec)

<http://www.youtube.com/watch?v=eybnVOMEX6w>

Discover how New York City has implemented Complete Street design and how it has improved conditions for bikers, bus riders, and others.

# A Street for Everyone

Student  
handout

**Your Challenge:** Discover how streets are classified and redesign a local street to be a Complete Street.

- Use the chart below to classify streets in your city on the map your club leader will show the group.

Functional System	Services Provided
Arterial	Provides the highest level of service at the greatest speed for the longest uninterrupted distance, with some degree of access control. Specific characteristics: not meant to provide access to residential properties; 30–50 mph speed limit, 4–10 lanes wide; usually use traffic signals.
Collector	Provides a less highly developed level of service at a lower speed for shorter distances by collecting traffic from local roads and connecting them with arterials. Specific characteristics: 20–35 mph speed limit; 2–4 lanes wide.
Local	Consists of all roads not defined as arterials or collectors; primarily provides access to land with little or no through movement.

Source: *Flexibility in Highway Design: Chapter 3: Functional Classification*  
<http://www.fhwa.dot.gov/environment/publications/flexibility/ch03.cfm>

## Materials:

- Computer
- URL of the cross-section of the street chosen for redesign



## Design a Complete Street

Use the web-based Streetmix app to redesign a local street into a Complete Street

Start screen for Streetmix, a web-based app to that allows you to design your own street.  
[streetmix.net](http://streetmix.net)





## Design It!

- ① Use the URL your club leader has provided to load a copy of the street you will be redesigning.
- ② Use the Streetmix app to redesign the existing street into a Complete Street.
  - Name your street
  - Consider who all users of the street might be
  - Make sure you stay within the existing design parameters for the street
  - Share the URL to your street with your club leader when you are done (you can find and copy the URL from the “Share” drop-down menu in the upper right-hand corner)
- ③ Review your team’s design with the rest of the group when your club leader shares your street renovation, and explain why your team chose to design the street in the way it did.



## Connecting to the World

The Streetmix app may just seem like a fun tool, but citizens from coast to coast have been putting it to the test tackling real-world street design problems. In Seattle, one bike blogger used Streetmix to explore improvements for one of the busiest bike streets in the city. In Kansas City, Missouri, another citizen used Streetmix to sketch plans to present at a parking and traffic study kickoff meeting held by the Public Works Department. In Oklahoma, the University of Oklahoma posted a census of street designs on Oklahoma main streets and invited the public to use the Streetmix app to improve some of the state’s main streets. And in New Jersey, a member of the Tri-State Transportation Campaign added bike lanes in some proposed re-designs of New Jersey Department of Transportation’s cross-sections for Route 35 to help turn the roadway into a truly “complete” street. How might Streetmix be used in your city?



## Activity 3: Counting Cars (2 meetings)

### The Challenge:

Collect and analyze traffic data at a local intersection that is under stress from left-turning vehicles to determine capacity and level of service (LOS).

**Time:** 2 meetings (plus 15 minutes in a club meeting prior to this activity to help set up the traffic-counting field work in Part 1 of the activity).

**Overview:** : In Part 1, students conduct a traffic count at a busy local intersection with a traffic light (signalized) but without a dedicated left-turn lane. In part 2, students analyze the data, evaluate the intersection's capacity and level of service, and apply a growth rate to the traffic data.

### Learning Objectives:

Students will be able to:

- Describe what traffic counts and turning movements are and why they are important to collect.
- Determine how different parts of an intersection function.
- Construct a turning movement diagram with field data from a local intersection.
- Describe the concept of level of service and how it impacts transportation engineering.
- Apply a growth rate to current traffic data to project a design forecast.
- Decide if the intersection studied may need improvements now or in the future.

### Preparation:

- Prior to Meeting 1, complete the following to prepare for the Meeting 1 data collection activity:
  - Review the entire activity.
  - Choose a busy signalized intersection near your club host location where there is currently no dedicated left-turn lane (if possible, where you think there is an issue with clearing left-turning vehicles; ideally the intersection will have one or two lanes in each direction).
  - Obtain a close-up of the intersection from Google maps and make 4 copies (1 copy per team).
  - Decide what time of day the traffic count will occur (a higher-volume hour of the day is preferable).
  - Recruit 2–4 adult volunteers to help during the traffic counting.
- **Gather materials**  
For Meeting 1:
  - Copies of “Counting Cars” student handout (1 per student and adult volunteer).

The  
**Big  
Idea!**

Data collected from well-designed research projects can help transportation managers better understand how roadways are functioning.

Research about roadways can be done at local, state, or national levels. One federal organization, the Transportation Research Board (<http://www.trb.org/Main/Home.aspx>), funds interdisciplinary research worldwide to find innovative solutions for transportation problems. Each year, the board awards more than \$50 million in transportation research in the fields of highway, transit, airport, rail, freight, and hazardous materials transport.

Engineers look to research for answers to questions of all kinds, including those relating to issues of capacity, construction, design, economics, environment, forecasting, maintenance, policy and planning, safety, security, traffic planning, and more.

One type of research related to traffic planning is called queuing theory, which is the mathematical study of waiting in lines. Aircrafts waiting to take off, automobiles arriving at a tollgate, freeway bottlenecks, and ships steaming toward port are all examples of transportation queuing problems. Engineers use the principles of queuing theory to help develop and evaluate traffic models.

 **Video Link: Stay in Queue**  
(1min 36sec)

<http://www.go-explore-trans.org/waiting-in-line>

Clever animation that demonstrates what happens to one queue-jumping bear. The video is one component of a website that describes how queuing theory is used for solving traffic problems. The site includes a link to an activity in which students collect and analyze data about queues that form in a high school cafeteria.

- Copies of the “Traffic Count Field Sheet” student handout (Note: choose the handout that goes with the number of lanes you will be studying) (1 per student).
- Stopwatch or watch to keep track of time (1 per adult volunteer).
- Clipboards or similar writing surfaces to use in the field (1 per student and adult).
- Pencils with erasers (1 per student and adult volunteer).
- Safety vests meeting current standards (1 per student and adult volunteer).
- Optional: Clicker counters for keeping track of traffic (if available) (1 per student).

For Meeting 2:

- Copies of the “Data Crunch” student handout (1 per team).
- Calculator (if students have smartphones, they can use the calculator app on the phone) (1 per student).
- Copy of the “Traffic Count Data Summary” leader sheet.
- Presentation equipment for displaying the “Traffic Count Data Summary” leader sheet, and method for marking student data results on sheet.



## Prior to Meeting 1

### ① Setup Traffic Counting (5 minutes)

- In the club meeting prior to doing this activity, ask students to think about driving or riding around in their city. Does it seem like they breeze through the city on some roads while sitting in traffic forever at others? Are there some places where it’s easy to turn left, while others seem nearly impossible, and even dangerous? Tell them these are the types of things that engineers think about all the time. Traffic engineers want to design roadways that are both efficient and safe. They need to understand how much traffic is in a given area and how it moves to be able to efficiently improve roads, highways, subways, trains, or even bicycle paths. One way they learn about traffic loads is through traffic counts.
- Inform students that they will be doing a one-time traffic count to better understand traffic flow and turning movements at an intersection with a traffic light (known as a signalized intersection).
- Explain that traffic is typically traffic counted in several ways: placing pneumatic tubes on a road to collect data from the vehicles that drive over them, using a digital camera to shoot footage that is later reviewed to count vehicles, or sending out people who count traffic manually, similar to what students will be doing.

### ② Review Traffic Count Field Work (10 minutes)

- Distribute and review with students the “Counting Cars” student handout.
- Provide a brief introduction about how the traffic count will be conducted during the next meeting.
- Check with your Club’s faculty advisor about whether the traffic counting activity is considered a field trip and needs any parental permission; secure permissions as needed.
- Recruit your volunteers, and give each a copy of the “Counting Cars” handout and review the traffic count activity with them. Point out that volunteers will be responsible for keeping track of the time that has been decided to spend out in the field (suggested time is 15–30 minutes).



## Part 1: Traffic Counting (60 minutes)

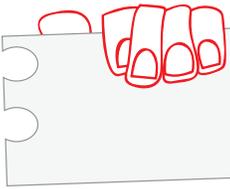
### ① Review the Field Work (10 minutes)

- Organize students into four teams. If possible, assign at least three students to each team (one student to cover each of the three possible vehicle movements). If more than three students are on a team, students can double up on coverage on traffic movements.
- Pair up volunteers with student teams (two volunteers would have two teams each, four volunteers would have one team each). Distribute the clipboards, pencils, and safety vests to all students and adult volunteers (and make sure adults have a stopwatch or watch to keep track of time). If available, distribute clicker counters to students.
- Distribute copies of the “Traffic Count Field Sheet: One Lane” OR “Traffic Count Field Sheet: Two Lanes” data sheet depending on how many lanes of traffic are in the intersection being studied.
- Distribute copies of the Google map you printed of the intersection you chose. Assign teams to a direction from which to watch vehicles, and have each team mark on the map where they will be stationed during the activity (students will be at either two or four locations at the intersection depending on how many adult volunteers are helping out):
  - Team A: Northbound vehicles
  - Team B: Eastbound vehicles
  - Team C: Southbound vehicles
  - Team D: Westbound vehicles
- Have each team of students decide within the team who will be counting and recording which of the following vehicle movements:
  - left-hand turn
  - straight through the intersection
  - right-hand turn
- Have each team also review which team members will be responsible for keeping track of whether the final car in queue at the end of the red cycle clears the light during the green phase. (The team member or members who track this vary depending on whether the intersection being studied has one or two lanes of traffic. The “Traffic Count Field Sheet” handout includes specific instructions in accordance with the number of lanes).
- Clear up any questions students might have before heading out to count traffic.

### ② Evaluate/Test (50 minutes)

- Visit the intersection site and conduct the traffic count. The count should be performed over a 15- to 30-minute period for a more effective use of time, and can be scaled up to an hour’s worth of counts. Remind volunteers that they will be responsible for keeping track of time.
- Observers should be positioned where they have a clear view of the traffic, but are away from the edge of the roadway.
- Volunteers should help students if they are having trouble watching or counting the vehicles. If the intersection is very busy and students are having trouble keeping up with counts, estimates are fine. Students can count by two if needed.
- Return to the club space after the traffic count and collect student handouts and safety vests.
- Let students know that at the next meeting they will be sharing and analyzing the data they collected.





## Part 2: Capacity and Level of Service Analysis (60 minutes)

### ① Crunch Data (20 minutes)

- Distribute the “Data Crunch” student handout and calculators to each team. Have students fill out the tables on the handout using the data they collected during their field work, and perform the calculations needed on their data.
- Once students have filled out the tables, review the first Turning Movement Sample Diagram on students’ “Data Crunch” handout that shows how engineers report turning movements. Tell students that the numbers in the sample diagram represent **Average Daily Totals (ADT)** for that intersection for one day, which is how traffic engineers typically show intersection turning movements.
- Following the review, have students create their own Turning Movement Diagram using the data they collected for the direction they were watching.

### ② Evaluate/Test (50 minutes)

- Once all teams have entered their data, have each team report its results for:
  - the Cycle Data (final average percent loaded)
  - the Turning Movement Diagram ADTs for each movement, and the sum of the ADTs for each direction
- Write each teams’ results into the correct table or diagram on your “Traffic Count Data Summary” leader sheet being projected on the overhead.
- Introduce two ways that engineers assess roadway efficiency: Capacity and Level of Service (LOS). Capacity is a measure of how many cars a road can handle, how many trains a railroad can handle, or perhaps how many people a subway system can handle during a given period of time under prevailing conditions. It provides a quantitative measure of a facility, and is usually obtained through field observations. Capacity is usually expressed in terms of vehicles per hour, passenger cars per hour, or persons per hour. Level of service, on the other hand, tries to define the quality of a road’s present traffic situation. It is both a quantitative and a qualitative measure of operational conditions, such as speed and travel time, density of traffic, driver comfort and convenience, and delays. LOS grades range from A through F, with A representing the best range. LOS can be used to quickly analyze the existing condition at the intersection.
- Look at the Cycle Analysis data with students. How well was each road in the intersection able to handle the capacity the day and time they took the data? Were all the cars cleared during each light cycle? How did the four different directions compare in terms of clearing the cars during each light cycle? If there were marked differences in percent loaded across the light cycles, what might account for that? (There may have been heavy vehicles [e.g., trucks, buses, RVs] in some of the cycles, which would affect the counts because they take up more roadway space and are often not able to keep pace with passenger vehicles, thus at times allowing less traffic to clear. Traffic counts normally take into account heavy vehicles, but were not included in students’ field work to simplify the activity).
- Now discuss the level of service for each road in the intersection. Have students look at the average percent loaded numbers for each direction of the intersection they studied during a complete cycle (red to red signal). Then have students use the following LOS criteria below to assign each direction an LOS.

Level of Service	Clearance
A	everyone clears (0% loaded)
B	90% clears (10% loaded)
C	70% clears (30% loaded)
D	30% clears (70% loaded)
E/F	0% clear (100% loaded)

Source: Source: Tom Mulinazzi, Professor, University of Kansas, 2011.

- What levels of service do students determine the intersection to be operating at today based on the direction they watched? The lowest LOS out of the four directions is the intersection's overall LOS. Does it appear that left turns from any direction are impacting the entire intersection's function based on the movement data acquired? Discuss any other observations students had about the intersection during their field work. Did they see any pedestrians or bicyclists using crosswalks? Did that seem to impact traffic flow? In a final analysis, does it appear to students that a dedicated left-turn lane might be needed at any of the intersection's four roadways? Does it appear that a right-turn lane might be needed? Could the signal timing (or length of time for green for each movement) be improved to possibly help the heavier movements?
- Point out to students that they collected data for just a brief period of time at one time of the day during one day of the week, so their observations may not accurately reflect whether a dedicated left-turn lane is needed. Traffic planning decisions are usually based on much more data taken at multiple times of the day and week (and sometimes year), and that accident rates are also taken into consideration when deciding whether to modify roadways or intersections.

### ③ Forecast (10 minutes)

- What about the future? What if more people move into the area, or a new stadium draws crowds on certain days? Engineers must consider growth factors and their potential impact on how an intersection may be changed.
- What would happen if, projecting out 20 years, the traffic increased by 5% per year? (If you would like, substitute a projected design year and growth rates for your area.) Review the second Turning Movement Sample Diagram on students' "Data Crunch" handout that shows both the original data and also the forecasted data. (Note that the growth projections for the sample data below were 1.25% annually).
- Have students calculate the 5% projected increase for the traffic direction they studied, and add it to their original Turning Movement Diagram that contains the figures from their original traffic count. After they have calculated and added in the forecasted data, have each team report their results for the class. Write each team's results onto the Turning Movement Diagram on the leader sheet being projected on the overhead.
- Compare results and discuss what this may mean for the future. If the intersection or specific movements aren't failing now, are they likely to fail soon with increased traffic? Do students think an improvement should be made now, or should funds be spent elsewhere?

### ④ Wrap Up (5 minutes)

- Introduce the next meeting: Students will be designing a dedicated left-turn lane.

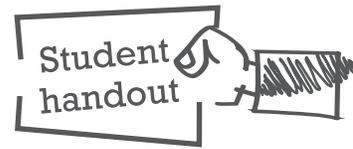


## Extensions

- **Learn more about level of service and congestion.** Use parts or all of the “What’s Up with All This Traffic?” lesson from TeachEngineering.org to help students discover two ways level of service is determined and the mathematical procedure to derive traffic density using the units of measurement for speed and flow. Find it at [http://www.teachengineering.org/view\\_lesson.php?url=collection/usf\\_/lessons/usf\\_traffic/usf\\_traffic\\_lesson01.xml](http://www.teachengineering.org/view_lesson.php?url=collection/usf_/lessons/usf_traffic/usf_traffic_lesson01.xml) - objectives.
- Introduce students to real-world traffic simulations. Traffic engineers create and use traffic simulations to better help plan, design, and operate transportation facilities. Simulations are created using computer programs that mathematically model traffic flow. Show students some of the following simulations:
  - **The Phantom Traffic Jam: An Explanation (2min 35sec)**  
<https://www.youtube.com/watch?v=goVjVVaLe10>  
Video shows how a phantom traffic jam—one that seems to have no visible cause—occurs on a congested UK highway. Followed by a traffic simulation revealing what happens once the roadway becomes clogged with traffic.
  - **Chicago Traffic Microsimulation (1min)**  
[https://www.youtube.com/watch?v=ZQO\\_gwLMIPQ](https://www.youtube.com/watch?v=ZQO_gwLMIPQ)  
A microsimulation model of Chicago Traffic created by the TRACC center at Argonne National Laboratory.
  - **Traffic and Pedestrian Modelling: Los Angeles (1min 17sec)**  
<https://www.youtube.com/watch?v=AygCSbZh60s>  
This microsimulation model of LA Live, a downtown Los Angeles destination for entertainment and events; model includes both vehicles and pedestrians.
- **Ask students to look at local intersections without a dedicated left-turn lane during a busy time of day.** Have students evaluate if a dedicated lane is warranted. If so, ask students to list reasons why there is not one. Reason might include:
  - level of service is high even without a dedicated turn lane
  - right-of-way issues prevent addition of a turn lane
  - although growth or development may have occurred, no one has complained or there has been no significant increase in reported crashes
  - no available funding
- **Invite a city engineer to talk about local traffic capacity and level of service.** Ask a city engineer to visit the club to discuss how the city decides when to collect traffic data and how it uses the data to inform planning decisions. Have the engineer also discuss other factors involved with deciding to make any traffic flow changes, such as city policy, community input, and budget.



# Counting Cars

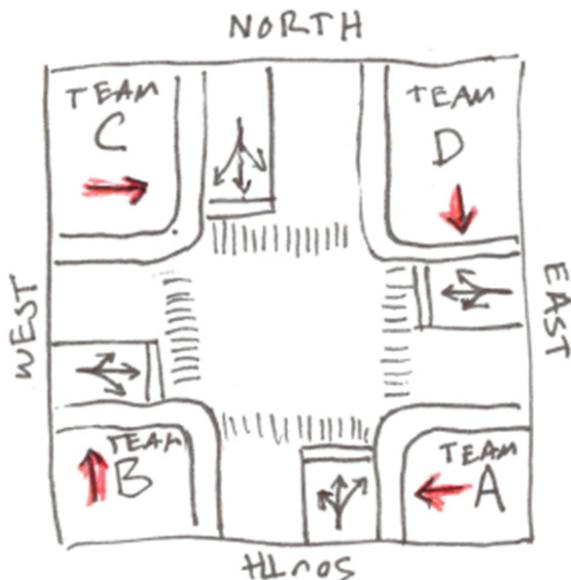


**Your Challenge:** Collect and analyze traffic data at a local intersection that is under stress from left-turning vehicles to determine capacity and level of service.

How to Watch and Count the Vehicles

 You will be assigned to watch vehicles traveling in one of four directions for 15–30 minutes:

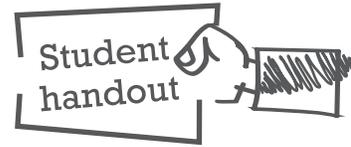
- |                                    |                                    |
|------------------------------------|------------------------------------|
| <b>Team A:</b> Northbound vehicles | <b>Team C:</b> Southbound vehicles |
| <b>Team B:</b> Eastbound vehicles  | <b>Team D:</b> Westbound vehicles  |



- One or more members of your team will be responsible for watching and counting vehicles 1) turning left, 2) going straight through intersection, or 3) turning right.
- Some team members will also track how many vehicles clear the light from a red-to-red cycle.

- Materials:**
- Clipboards
  - Pencil
  - Safety vests

# Traffic Count Field Sheet: One Lane



**This team is watching traffic traveling (circle one):**

Northbound Southbound Eastbound Westbound

Name of Person Counting Cars **Turning Left:** \_\_\_\_\_

- When the light turns green, place one tick mark for each car in “# Vehicles Cleared” for all cars that turn left.

Name of Person Counting Cars **Turning Right:** \_\_\_\_\_

- When the light turns green, place one tick mark for each car in “# Vehicles Cleared” for all cars that turn right.

Name of Person Counting Cars **Going Straight and Total Cars Not Cleared** \_\_\_\_\_

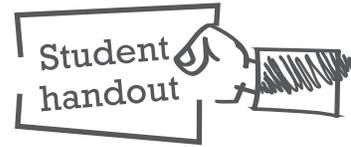
- When the light turns red, count the number of vehicles in line, including any that drive up before the light changes to green. Write that number down in the “# Vehicles Waiting” column. Remember what the last car looks like so you can tell if it makes it through the intersection before the next red light.
- When the light turns green, place one tick mark for each car in “# Vehicles Cleared” for all vehicles that drive straight through the intersection.
- When the light turns back to red, determine if the last car made it through the intersection. If not, how many remain including it and those in front of it? Write that number in the “# Vehicles Not Cleared.”



**Repeat the above process for each light cycle until the time is up.**

Light Cycle	# Vehicles Waiting	# Veh. Not Cleared	Left Turns	Straight	Right Turns
1	III				
2					

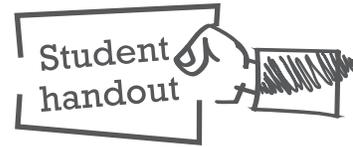
# Traffic Count Field Sheet: One Lane



Data Sheet

Light Cycle	# Vehicles Waiting	# Veh. Not Cleared	Left Turns	Straight	Right Turns
1 Example	11	3	II (2)	 (6)	I (1)
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

# Traffic Count Field Sheet: Two Lanes



This team is watching traffic traveling (circle one):

Northbound Southbound Eastbound Westbound

Name of Person Counting Cars **Turning Left**: \_\_\_\_\_

- When the light turns red, count the number of vehicles waiting in the left lane in line, including any that drive up before the light changes. Write that number down in the “# Vehicles Waiting” column. Remember what the last car looks like so you can tell if it made it through the light.
- When the light turns green, place one tick mark for each car in “# Vehicles Cleared” for all cars that turn left.
- When the light turns back to red, determine if the last car in the left lane you are watching made it through the intersection. If not, how many remain including it and those in front of it? Write that number in the “# Vehicles Not Cleared” column.

Name of Person Counting Cars **Turning Right**: \_\_\_\_\_

- When the light turns red, count the number of vehicles waiting in the right lane up until the end of the red cycle in line, including any that drive up before the light changes. Write that number down in the “# Vehicles Waiting” column. Remember what the last car looks like so you can tell if it made it through the light.
- When the light turns green, place one tick mark for each car in “# Vehicles Cleared” for all cars that turn right.
- When the light turns back to red, determine if the last car in the right lane you are watching made it through the intersection. If not, how many remain including it and those in front of it? Write that number in the “# Vehicles Not Cleared” column.

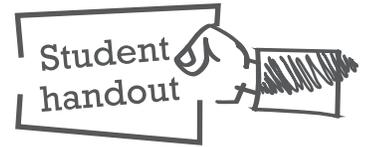
Name of Person Counting Cars That **Go Straight** (either lane): \_\_\_\_\_

- You can take it easy during the red lights—your partners are counting the waiting cars.
- When the light turns green, place one tick mark for each car in “# Vehicles Cleared” for all vehicles that drive straight through the intersection.



Repeat the above process for each light cycle until the time is up.

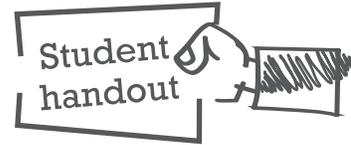
# Traffic Count Field Sheet: Two Lanes



Data Sheet

Light Cycle	# Vehicles Waiting (Left Lane)	# Vehicles Not Cleared (Left Lane)	Left Turns	Straight from left lane	# Vehicles Waiting (Right Lane)	# Vehicles Not Cleared (Right Lane)	Straight from right lane	Right Turns
1	10	3	IIII (5)	II (2)	11	0	IIII I (6)	IIII (5)
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

# Data Crunch



## Analyze Cycle Data

- Determine what the percent load for each light cycle by dividing the “# Vehicles Not Cleared” by the “# Vehicles Waiting.”

### Example from Traffic Count Field Sheet: One Lane:

**Light Cycle 1:** 3 vehicles not cleared/11 vehicles waiting = .27 or 27%

### Example from Traffic Count Field Sheet: Two Lanes:

$(3+0)/(10+11) = .136$  or 14%

- Record the result in the table below.
- Calculate and record the average percent loaded for all cycles.

Direction Assigned: \_\_\_\_\_

Light Cycle	Percent Loaded	Light Cycle	Percent Loaded
1		8	
2		9	
3		10	
4		11	
5		12	
6		13	
7		14	

Average % Loaded for All Cycles: Add the percent loaded figures for all light cycles recorded and divide by the number of light cycles. \_\_\_\_\_



## Analyze Movement Data

- Count up the total number of cars cleared for each of the three movements you tracked. Enter in the table below.
- Scale your total counts for each movement up to the vehicles per hour and vehicles per day (Average Daily Traffic, or ADT).

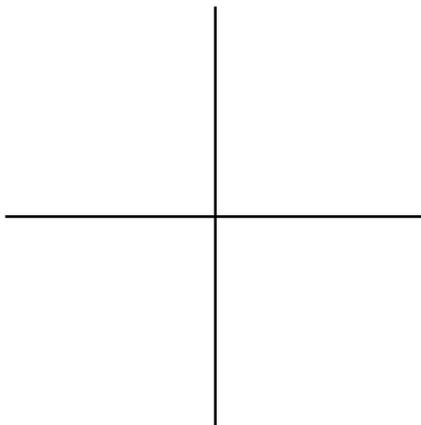
Your Team's Movement	Total Counts	Scale to Vehicles Per Hour (VPH)	Scale to Vehicles Per Day (Average Daily Traffic, ADT)
For example: Northbound to Westbound Left Turn Northbound Straight Northbound to Eastbound Right Turn			
<b>Movement:</b>			
Example: Westbound to Southbound Left Turn	6 in 15 minutes	$6 \times 4 = 24$ in 60 minutes (1 hour)	24 cars per hour x 24 hours per day = 576 cars per day



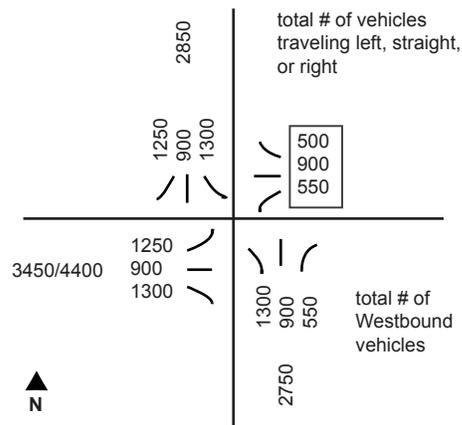
## Create a Turning Movement Diagram

- Write down the ADT for each of the three movement directions in the correct place on the Turning Movement Diagram. Sum the totals for each movement and record on the diagram.

Turning Movement Diagram

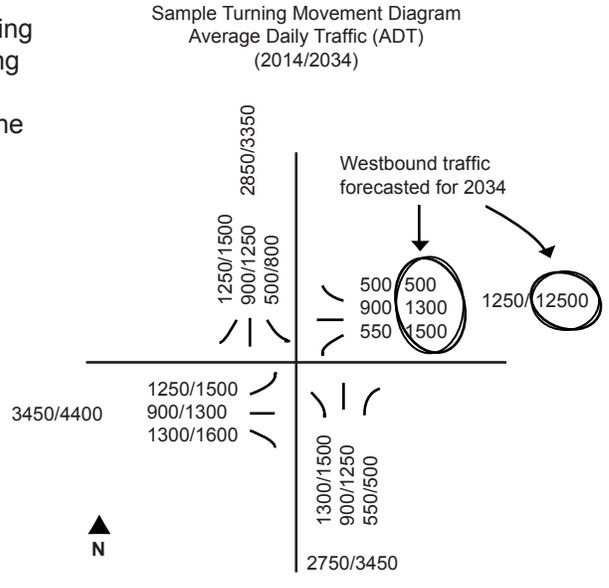


Sample Turning Movement Diagram  
Average Daily Traffic (ADT) (2014)



# Growth Projections

Calculate growth projections at 5% yearly for your turning movement data above. Add your results to your Turning Movement Diagram that contains your original traffic count data. The sample diagram below shows where the forecasted numbers should appear.



## Connecting to the World



Transportation engineers have long collected data about traffic patterns using people who count traffic manually, videos that record traffic, or machines that record when vehicles pass a certain point in the road.

But engineers have recently taken to tapping into big data—large, complex data sets—to help them do their jobs. In 2012, one group of engineers used large-scale mobile phone data and detailed Geographic Information System (GIS) data to uncover previously hidden patterns in urban

road design in the Boston and San Francisco Bay areas. And increasingly, cities are using what's known as Intelligent Transportation Systems (ITS) to provide services relating to traffic management; one application for this is the large electronic signs you might see overhanging the highway that display real-time traffic information. By better understanding how roads are used dynamically some researchers are hoping big data may help mitigate congestion and better increase level of service for drivers.

**Video Link:** How 'Big Data' Ends Traffic Jams (5min 20sec)  
<http://live.wsj.com/video/how-big-data-ends-traffic-jams/23C39528-C6D6-42BF-AC17-B40C04276005.html> - 123C39528-C6D6-42BF-AC17-B40C04276005

This Wall Street Journal video reports on how municipalities are using big data to help them manage traffic and transportation loads.

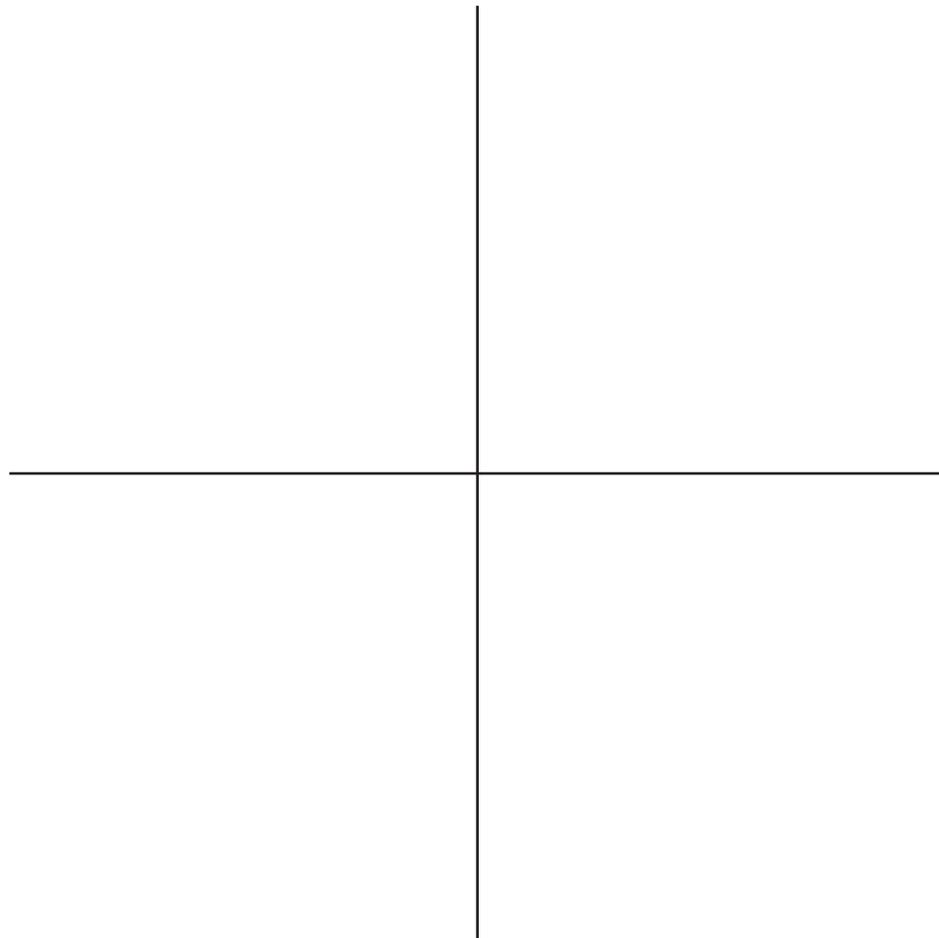


# Traffic Count Data Summary

Light Cycle	Team A Direction _____	Team B Direction _____	Team C Direction _____	Team D Direction _____
Avg. % Loaded				



## Turning Movement Diagram



## Activity 4: It's Your Turn (2 meetings)

### The Challenge:

Design a dedicated left-turn lane into an existing facility.

**Time:** 2 meetings (Note: Meeting 1 includes Part 1 and the beginning of Part 2)

**Overview:** In Part 1, students learn some of the design considerations that factor into street planning and design. In Part 2, students use data adapted from a real-world project to design a dedicated left-turn lane into an existing facility.

### Learning Objectives:

Students will be able to:

- Describe what a dedicated left-turn lane is
- List the benefits of a dedicated left-turn lane
- Understand design considerations for creating a left-turn lane
- Design a dedicated left-turn lane

### Preparation:

- **Review the leader notes** and try out the activity
- **Gather materials**

For Meeting 1:

- Copies of the "It's Your Turn" student handout (1 per student)
- Copies of the "Base Plan: Buckaroo Highway" handout (1 per student and 1 leader copy for projection)
- Markers in red, green, and blue for marking up "Base Plan" projected handout

For Meeting 2:

- Copies of the "Design It!" student handout (1 per student)
- Copies of "Base Plan: Buckaroo Highway" handout (1 per team)
- Copies of "Base Plan: Intersection Detail" handout (1 per team)
- Copies of the "Turning Templates" handout transferred to clear acetate (1 per team)
- Copies of "Final Plan: Buckaroo Highway" handout (1 per student)
- Drafting equipment (1 set for each team)
  - 1 engineering scale
  - 1 12-inch 30- to 60-degree triangle
  - 1 12-inch 45-degree triangle
- Red pencils with erasers (1 per student)
- Calculator (1 per team)
- Scissors (1 pair team)
- Clear tape (1 dispenser per team)

The  
**Big  
Idea!**

**Dedicated left-turn lanes keep traffic flowing and increase safety.**

Statistics help tell the story: A lane shared by left-turning and through-passing vehicles has about 40 to 60 percent less capacity than a standard through lane with no left turn, notes a Transportation Research Board report that synthesized major research on the topic. In addition, exclusive turn lanes reduced accident rates between 18 and 77 percent, with a median reduction of more than 50 percent. Rear-end accidents were reduced between 60 and 88 percent.

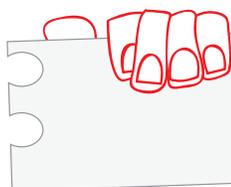
Traffic engineers can do a lot to help increase traffic safety, such as designing dedicated left-turn lanes where needed, but they can't do everything to prevent accidents. The best-designed road is only as safe as the drivers who use it. And there's an increasing threat to safety from rising rates of distracted driving. According to the National Highway Traffic Safety Administration, 10 percent of all drivers under age 20 involved in fatal crashes were reported as distracted at the time of the crash. And, according to a 2013 study in the journal *Pediatrics*, nearly half of all US high school students aged 16 years or older text or email while driving. Help students understand the dangers of distracted driving by sharing the links and videos below with them:

**For more on distracted driving, see**

<http://www.distraction.gov/index.html>  
[http://www.cdc.gov/motorvehiclesafety/distracted\\_driving](http://www.cdc.gov/motorvehiclesafety/distracted_driving)  
<http://www.cartalk.com/content/get-informed>

For Meetings 1 & 2:

- Presentation equipment for displaying the “Base Plan: Buckaroo Highway” and “Final Plan: Buckaroo Highway” handouts
- **Familiarize yourself with the Design Considerations information** on the “It’s Your Turn” student handout so you can best assist students while they are creating their designs.



## Part 1: Need a Left? (55 minutes)

### ① Icebreaker (10 minutes)

- Ask students if they know what a dedicated left turn is. (A dedicated left turn is a lane specifically designed to accommodate left-turning vehicles. It may be at an intersection that does not have a traffic signal, an intersection with a traffic signal but no protected left-turn arrow, or an intersection with traffic signal and a protected left-turn arrow. Dedicated left-turn lanes can also be designed for turns into driveways of facilities such as shopping centers or businesses.)
- Have students provide examples in their community of intersections without a dedicated left-turn lane. What happens when a car wants to make a left turn and there is no dedicated lane? (The car needs to stop and wait for an opening. In the meantime, other cars stack up waiting to turn or waiting to continue straight through the intersection. When this left-turn movement causes a reduction in the level of service or a safety concern, it may be time to consider implementing a dedicated left-turn lane.)
- Ask students to list the benefits of a dedicated left-turn lane. (Benefits include improved safety through reduction of rear-end and broadside crashes in the direction of the approach and head-to-head collisions with oncoming traffic; improved capacity through the intersection by reducing delays and congestion and increasing travel speed; reduced vehicle emissions due to less congested traffic; and the potential for shorter cycle length and/or allocation of green time to other critical movements.)

### ② Introduce Design Considerations (20 minutes)

- Explain that for any engineering project there are regulations to follow, design data, constraints, controls, and sometimes client requirements to consider. Walk through each one of these for students. Point out to students that this list is a partial list of what an engineer must consider:
  - **Regulations:** These are set by some governing agencies and must be followed, such as taking into consideration predetermined measurements for certain variables. For example:
    - length of vehicles using the roadway
    - required lane widths
    - storage length (, a length sufficient to store the longest expected queue in order to prevent lane overflow)
    - taper length (, length of area where vehicles are channeled into the left-turn lane)
    - time it takes a vehicle to stop
  - **Design data:** This is the data that needs to be gathered in order to do the design. For example:
    - posted speed limit
    - number of vehicles expected during peak hour (, traffic counts)

- **Constraints:** A constraint is something that usually cannot be changed without a lot of effort and may limit the design. For example:
  - o width of the existing right-of-way
  - o location of existing utilities such as a utility pole
- **Controls/Existing conditions:** A control is something that dictates the design. For example:
  - o location of existing side streets or driveways
  - o physical minimum turning radius of design vehicles
  - o need for grading or clear zone due to road slope

### ③ Do a Concept Design (20 minutes)

- Walk students through a concept design to help them understand design considerations they will need to consider when doing their design.
  - Display the “Base Plan: Buckaroo Highway” drawing for students and explain the challenge: Based on traffic assessments, engineers have determined a dedicated left-hand turn is warranted from Buckaroo Highway into the Banzai Factory (the facility).
  - Begin the concept design by walking students through a set of “what ifs” and having them respond with what they think the consequences of each decision might be. Try not to give the answers but rather help students arrive at their own conclusions through guided questions such as:
    - o What are some ways the road might be widened to accommodate the new lane? (The road could be widened on either, or both, side[s]).
    - o What if a dedicated left turn were to be added to the northern side of the lane? (mark on the plan in red) (The boundaries of the northern side would need to widen but would still be within the road right-of-way [the property lines]).
    - o What if the left turn were added to the southern side of the road? (mark on the plan in green) (The boundaries on the southern side would need to widen, but Driveway A would likely also have to be modified which would be an additional expense and pose a problem for people using the drive).
    - o What if both sides of the highway were widened evenly? (mark on the plan in blue) (If both sides were widened evenly the travel lanes in both directions would be affected).
  - Next, talk about the design considerations for a left-turn lane. Draw in each of these elements as you guide students through them. Some possible questions include:
    - o Where should the car stop before it makes the turn? Sketch the car in several places and ask students if each stopping place seems like it would allow for a car to properly turn. (If students don’t mention it, ask whether it would make any difference if the vehicle were a passenger car, a flatbed truck, or a semi-trailer?).
    - o Which car-turning radius should be used to determine where to put the stop bar? (Engineers use the radius of largest design vehicle that will be using the intersection).

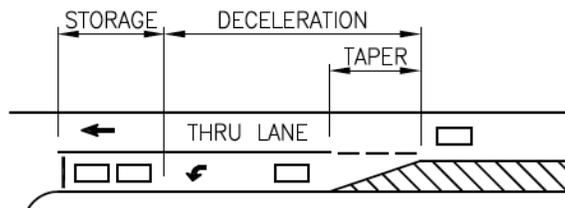


Figure 1. Components of a Left-Turn Lane

## Turning-Lane Length

- What happens to the existing lane when you add in the new dedicated left-turn lane? (There is no longer enough room for through-passing cars to travel.)
- How could the roadway be changed to accommodate through-passing traffic? (By creating a lane and related transition).
- What might be needed to create the lane transition? (The existing pavement would need to be widened over a certain length, and a new pass-through lane designed to complement the new left-hand turn).

### Part 2: Design a Left-Turn Lane (5 minutes)

①

#### 1) Introduce Challenge (5 minutes)

- Tell students that at the next meeting they will be designing their own left-turn lane. Distribute the “It’s Your Turn” and “Base Plan: Buckaroo Highway” student handouts to each student.
- Review the “It’s Your Turn” handout with students and ask them to think about where they would locate the left-turn lane based on what they learned in Meeting 1.
- Tell students that in the next meeting, they will receive more information about the design challenge and work with team members to complete the design.
- Ask students to bring back their “Base Plan: Buckaroo Highway” handout at the next meeting with the lane drawn in where they think the left-hand turn lane should be.





## Part 2 (continued): Design a Left-Turn Lane (60 minutes)

### ② Discuss Lane Placement (5 minutes)

- Start the meeting by asking students where they think the best place to site the lane is and why. After a short discussion, let students know that the project they are working on is adapted from a real-world design. In this case, the professional engineers chose to site the lane on the north side of the road. Reasons for this include:
  - The north side placement does not require modifications to the existing driveway.
  - All widening can be done within the right-of-way and no land acquisition is required [also applies to south side].
  - The expansion does not increase in the total number of travel lanes, and introduces a median space for a turning lane [also applies to south side].
  - There are no developments on the north side, so disruption due to the construction would not impact existing access.
- Distribute the remaining handouts and materials students will use to complete the design challenge:
  - “Design It!” student handout (1 per student)
  - “Base Plan: Buckaroo Highway” handout for the final design (1 per team)
  - “Base Plan: Intersection Detail” handout (1 per team)
  - “Turning Templates” handout transferred to clear acetate (1 per team)
  - Drafting supplies, pencils with erasers, calculators, and scissor and tape (see Materials List for quantities)
- Now that it has been established where the left-turn lane will be sited, review the rest of design components that students will be implementing:
  - Establishing where a vehicle should stop.
  - Determining how long to make the left-turn lane.
  - Deciding on the length and width of any lane shifts.
- Inform students that all the information they need to design the left-hand turn is in their handouts.
- Students will be drawing to scale their left-lane components on the “Base Plan” handout. Review with students how to use an engineering scale and answer any questions they may have about using it before beginning the design activity.
- Let students know that this activity does not take into account additional factors a traffic engineer would have to consider, such as whether a light should be at the intersection or whether the land would need to be re-graded to improve sight distance. This project is only looking at geometrics, which deal with the proportion of physical elements of highways, such as vertical and horizontal curves and lane widths

### ③ Design the Left-Turn Lane (40 minutes)

- Organize students into teams of three or four.
- Review the instructions on the “Design It!” student handout with students. Answer any questions they may have about the design challenge. Since the left-hand turn design will span both segments on the “Base Plan” handout, have students cut out the two highway segments at the dashed lines and tape the segments together to form one long strip. (You may want to note to students that engineering plans often have break lines like the ones shown on the student handout.)
- Have students work in teams to complete their designs.
- Walk around and assist each team as it works on its design.

### ④ Share Results (10 minutes)

- Have each team share its design, including where they put the stop line, how long they made the storage, taper, and deceleration lanes, and how they designed the lane transition. Did teams all design the same storage length? (Though the length of two passenger cars and a single unit truck

or bus would add up to 68 feet, students should add some additional space to account for space between vehicles. Design lengths ranging from 75–80 feet would be acceptable). The same length for the lane shift? Visually, does each group’s plan look the same? After all teams have shared, ask if anyone now sees a more optimal solution to the problem.

- Distribute and display the “Final Plan: Buckaroo Highway” handout for students explaining this was how professional engineers solved the problem in real life. Review each of the dimensions on the plan. The concept for the left-turn lane into Banzai Factory is based on four lengths: 550 feet for the lane shift of the northbound lane, 165 feet for the taper for the left-turn lane, 485 feet for deceleration, and 75–80 feet for storage of vehicles waiting to turn left from the left-turn lane. How did teams’ designs compare to the final? Discuss any differences.

### ⑤ Wrap Up (5 minutes)

- Ask students to summarize what they learned from designing a dedicated left-turn lane. What would be the consequences of making a turn lane too short? (The lane may not hold enough vehicles to be functional or safe). Too long? (Drivers may be confused and not realize they are in a turn lane, plus extra length means extra costs for construction of the lane and lane transition). Are there places within the community that students think could benefit from the addition of a dedicated left-turn lane? If so, does it seem like there would be enough room to add one without encountering right-of-way issues?



### Extensions

- Invite an engineer to present. Ask an engineer from local government or a private organization to present a design for a dedicated left-turn lane.
- Have students investigate other ways to improve traffic flow. Other methods besides left-turn lanes exist that can improve traffic flow and safety, including:
  - **ramp metering** (regulation of the flow of traffic entering highways; usually accomplished using a traffic light combined with a signal controller).
  - **high-occupancy lanes** (special use freeway lanes designated for the exclusive use of vehicles with a driver and one or more passengers).
  - **roundabouts** (road junctions in which traffic flows almost continuously in one direction around a central island; roundabouts are a potential solution for intersections with many conflict points).



## Video Link: Distracted Driving (play times vary)

<http://www.youtube.com/playlist?p=PL337F74DED367FDE7>

More than 20 brief videos from the National Safety Council on cell phone distracted driving, including answers to FAQs, different perspectives on the topic, and victim impact stories.

# It's Your Turn

**Your Challenge:** Design a dedicated left-turn lane into an existing facility.



## Take a Look Around

When you are walking, driving, or riding around in your city this week, look at left-hand turns. How long do they seem? What shape are the lanes designed in? How long are the cars and trucks on the road? Where do vehicles stop if they are the first to enter the lane? How far do they stop from the car in front of them?

## Materials:

- Copy of “Base Plan: Buckaroo Highway” handout

## Important

- Before your next club meeting, think about possible places you could add a left-hand turn to Buckaroo Highway.
- Sketch in on your “Base Plan: Buckaroo Highway” handout where you think the best place would be for a left-hand turn to go.
- At your next club meeting, you will be assigned to a team to actually design the turn lane.

# Design it!

Student  
handout

- ① Cut out the two highway segments at the dashed lines and tape the segments together to form one long strip.
- ② Decide where in the roadway you will put the dedicated left-turn lane.
- ③ Establish where a vehicle should stop at the intersection before turning (called the stop bar). Use the “Turning Templates” handout and “Base Plan: Intersection Detail” to determine where the stop bar should be placed based on the turning radius for the design vehicles. Draw the stop bar line in at scale on your team’s “Base Plan: Buckaroo Highway” handout.
- ④ Determine how long to make the left-turn lane, which is comprised of storage and deceleration length, which includes the taper. Draw each in to scale on the “Base Plan: Buckaroo Highway” handout.
- ⑤ Decide on the length and width of any lane shifts required by the addition of the dedicated left turn. Draw this to scale on your “Base Plan” handout.
- ⑥ When you have completed your design, share it with the group.

## Materials:

- Copy of “Base Plan: Buckaroo Highway” handout
- Copy of “Base Plan: Intersection Detail” handout
- Copy of “Turning Templates” handout on clear acetate
- Drafting equipment (1 set per team)
  - 1 engineering scale
  - 1 12-inch 30- to 60-degree triangle
  - 1 12-inch 45-degree triangle
- Pencil with an eraser
- Calculator
- Scissors and tape



## Design Considerations

### • Highway Description

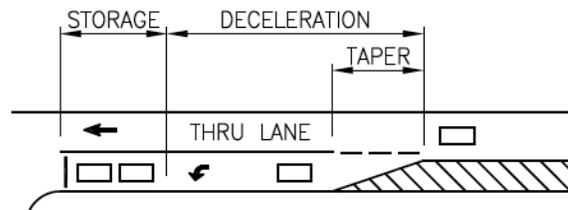
Buckaroo Highway is a two-lane major roadway. The right-of-way width is 100 feet, and travel lanes are approximately 11 feet wide. The posted speed limit is 50 miles per hour (mph). Existing access to the Banzai Factory is provided by one driveway (Driveway A) along the south side of Buckaroo Highway.

### • Driveway A Intersection

Driveway A is 35 feet wide and will primarily be used for employee parking, visitors, and deliveries. This use indicates that most vehicles will be passenger cars and small trucks. A passenger car (P) has a minimum inside turning radius of 15.3 feet, and single-unit truck (SU) has a minimum inside radius of 28.4 feet. (See "Turning Templates" handout for turning radius diagrams for design vehicles.)

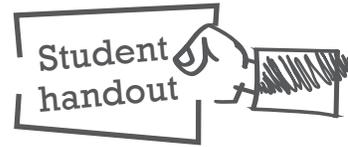
### • Left-Turn Lane Elements

The length of a left-turn lane consists of storage and deceleration length, which includes the taper.



**Storage Length:** Storage length should be provided for the number of turning vehicles likely to arrive in an average two-minute period within the peak hour. Based on Traffic Impact Analysis Report (TIAR) recommendations, the storage length should be designed to accommodate 3 vehicles (2 passenger vehicles and 1 single unit truck or bus). Consider the need for space between vehicles when determining storage length.

**Taper:** The Statewide Design Manual for Streets & Highways recommends a taper rate between 8:1 (lane width in feet [8] per every [1] foot of lane width) for design speeds up to 30 mph, and 15:1 for design speeds 35 mph to 50 mph.





## Connecting to the World

### Goodbye Left?

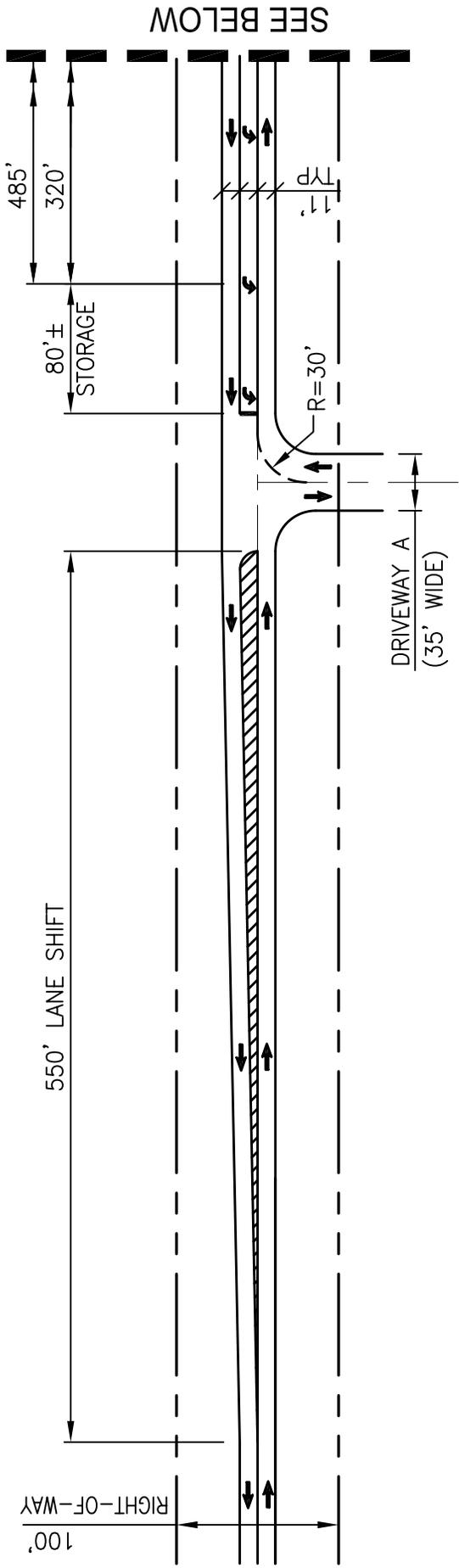
In an effort to optimize efficiency, United Postal Service engineers years ago came up with a simple rule to improve drivers' routes: minimize, or if possible eliminate, left turns. That simple change added up to about 10 million gallons of gas saved since 2004. Plus, a reduction in carbon emissions of 100,000 metric tons, equal to taking 5,300 cars off the road for an entire year.

But if some traffic engineers have their way, someday UPS may not have to worry about left turns at all. A new type of road design is gaining popularity: the diverging diamond interchange. Known as the DDI, the interchange streamlines traffic and prevents drivers from having to cross opposing traffic when making left turns.

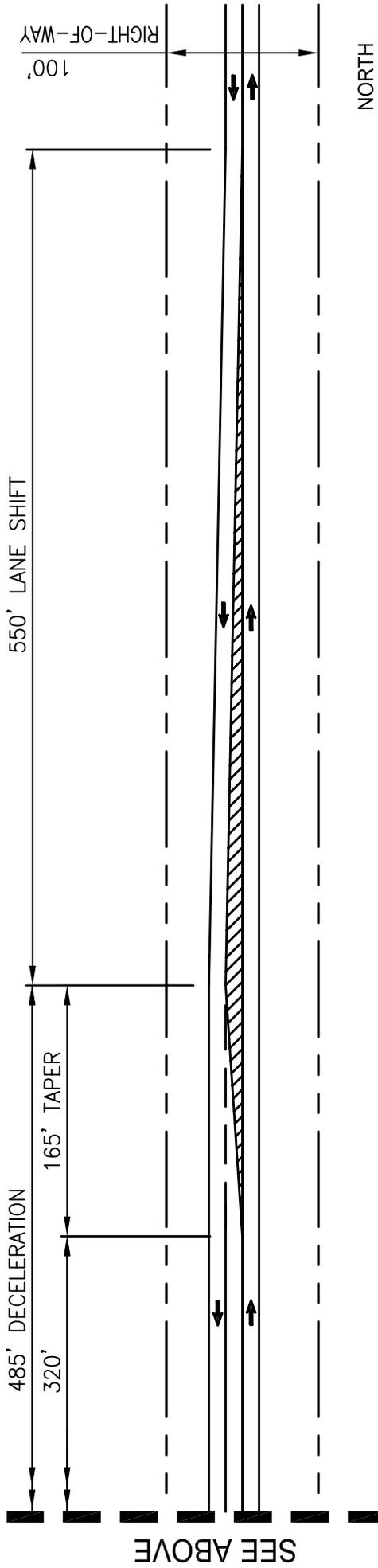
The brainchild of engineering graduate student Gilbert Chlewicki, the nation's first diverging diamond interchange was completed in 2009 in Springfield, Missouri. See how it works in this US Department of Transportation's Diverging Diamond Interchange Visualization (2min 51sec): <http://www.youtube.com/watch?v=HD-0QnUILOQ>

For a more in-depth explanation of how the DDI works, see the US Department of Transportation Federal Highway Administration's video, Alternative Intersections: Diverging Diamond Interchange (7min 39sec): <https://www.youtube.com/watch?v=eLAWwl3EtN4&feature=youtu.be>





BANZAI FACTORY



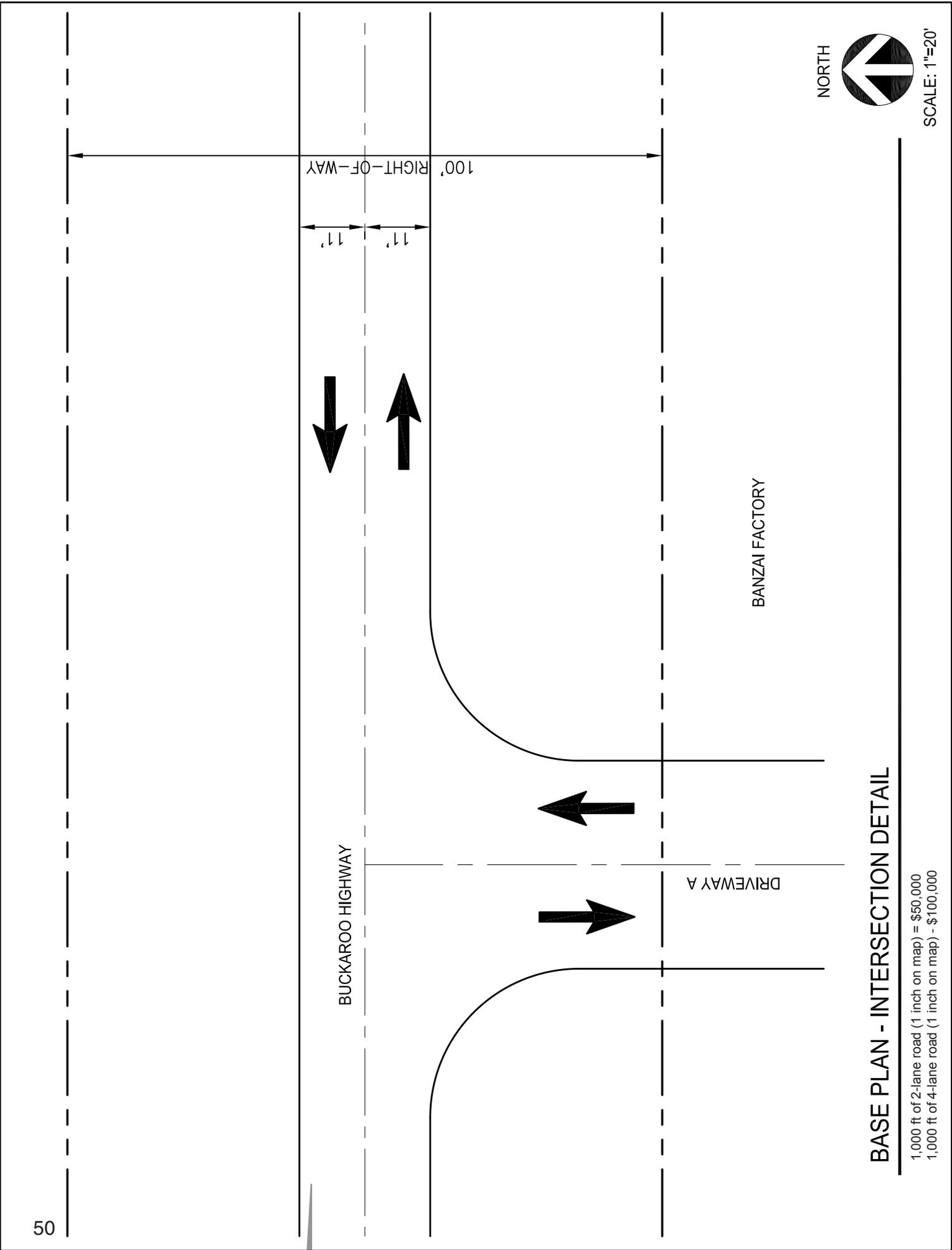
NORTH



SCALE: 1"=100'

### FINAL PLAN - BUCKAROO HIGHWAY

1,000 ft of 2-lane road (1 inch on map) = \$50,000  
 1,000 ft of 4-lane road (1 inch on map) = \$100,000



NORTH

SCALE: 1"=20'

**BASE PLAN - INTERSECTION DETAIL**

1,000 ft of 2-lane road (1 inch on map) = \$50,000  
 1,000 ft of 4-lane road (1 inch on map) = \$100,000

These templates were designed to show the right turning radius for these two types of vehicles. Just flip this handout over to use them to determine the radius you will need for a left-hand turn.

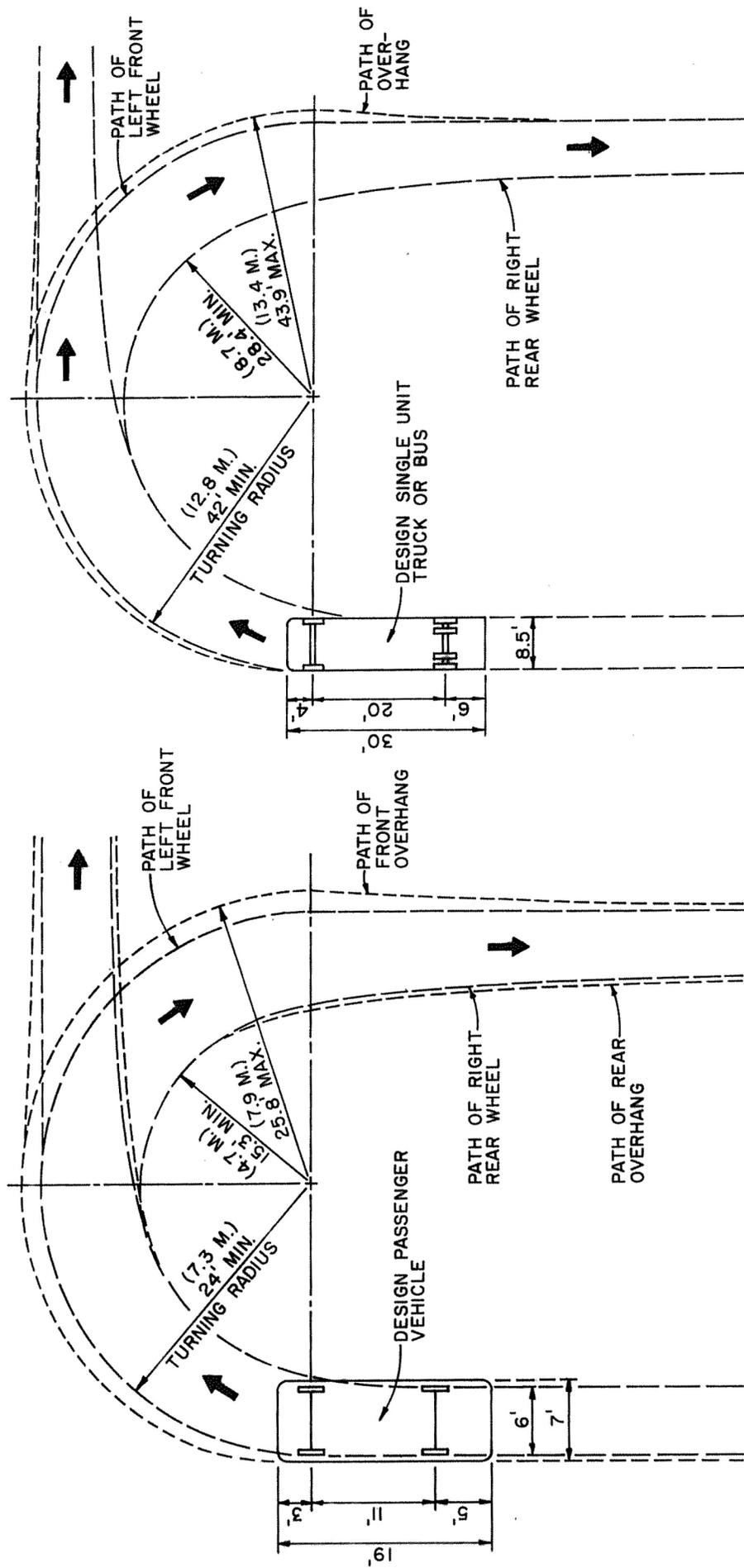


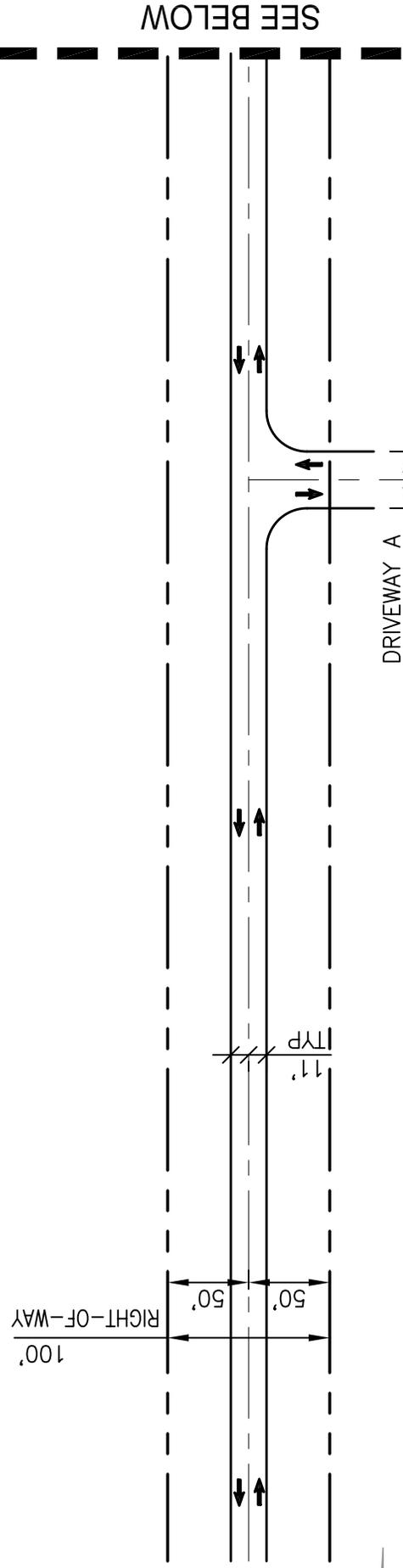
FIGURE 6-D

**MINIMUM TURNING PATH FOR P DESIGN VEHICLE**

FIGURE 6-E

**MINIMUM TURNING PATH FOR SU DESIGN VEHICLE**

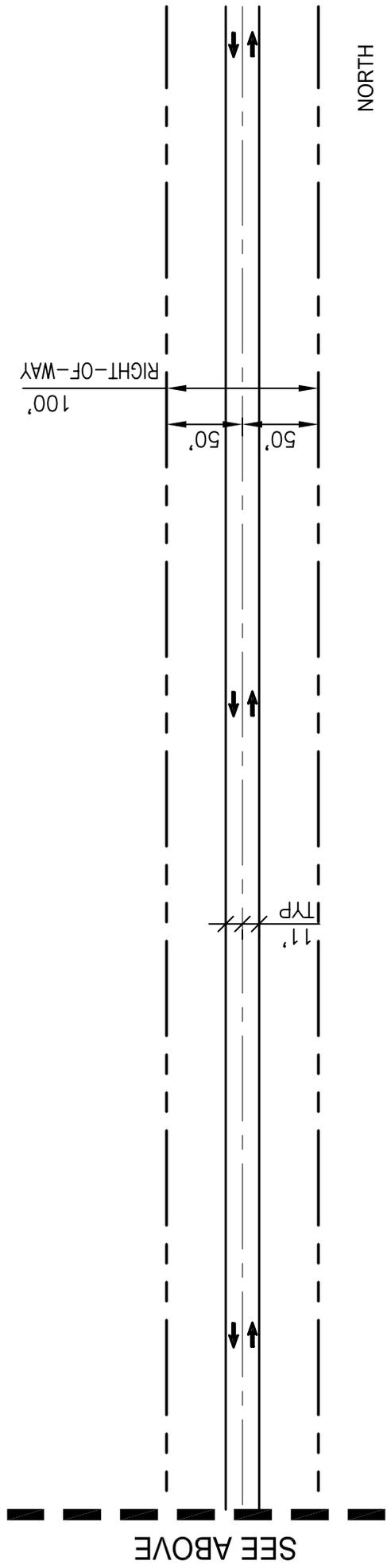
Source: Statewide Uniform Design Manual for Streets and Highways, State of Hawaii Department of Transportation, October 1980.



DRIVEWAY A  
(35' WIDE)

BANZAI FACTORY

CUT LINE



NORTH

SCALE: 1"=100'

**BASE PLAN - BUCKAROO HIGHWAY**

1,000 ft of 2-lane road (1 inch on map) = \$50,000  
 1,000 ft of 4-lane road (1 inch on map) = \$100,000

# Activity 5: Retaining Wall Challenge

## (1 meeting)

### The Challenge:

Design and build two small-scale mechanically stabilized earth walls (MSEW) with different reinforcement strategies, and load them to failure.<sup>1</sup>

**Time:** 1 meeting

**Overview:** Students use two plywood boxes as platforms to build and test small-scale retaining walls, each employing a different soil reinforcement strategy. Final walls are subjected to increasing loads until they collapse.

### Learning Objectives:

Students will be able to:

- Explain the function of a retaining wall.
- Describe how a mechanically reinforced wall is constructed.
- Recognize the lateral stresses that are caused by an applied vertical force.
- Describe the forces acting against a wall.
- Understand that reinforcing soil strengthens it.

### Preparation:

- Review the leader notes and student handout.

### Gather materials

For Sand Wall Demonstration (for leader use):

(all of the materials for the demonstration can be used with materials obtained for the student experiment)

- 50–55 pounds of dry sand
- 5- to-10-pound stackable weights, such as bricks, for testing wall strength
- Hand scoop, such as a large plastic cup
- 1 wood box with removable bulkhead or 1 Really Useful BoxR 8-Liter with hinged front (Office Depot Stock #452279)
- **For Student Experiment:**
  - Copy of the “Retaining Wall Challenge” student handout (1 per team)
  - 50–55 pounds of dry sand (make sure sand is dry as moisture

<sup>1</sup>Adapted from: *The “Mechanically Stabilized Earth (MSE) Wall” activity taught annually at Montana State University’s Summer Transportation Institute. Courtesy of Professor Robert Mokwa, MSU Department of Civil Engineering.*

# The Big Idea!

**Reinforcing soil increases its strength.**

Size matters when it comes to soil: One of Earth’s natural resources, soil is classified into three groups by its dimensions—sand (ranging from 2.0 mm to 0.05 mm), silt (0.05 mm to 0.002 mm), and clay (less than 0.002 mm).

While gardeners are interested in how well soil grows plants, geotechnical engineers are interested in how well soils hold together and how they behave under stress. Soils that stay together on their own are called cohesive (think of rainy-day mud sticking on your shoe); non-cohesive soils on the other hand, like sand or gravel, don’t bond together well at all.

Regardless of their ability to hold together, sand and gravel exhibit high degrees of strength when structurally confined. The added benefits of being relatively low cost and highly available make these aggregates a prime choice for construction use.

Soils can be made even stronger when reinforced. Increasingly, engineers are using geosynthetics to reinforce soil in highway retaining walls or under roadbeds. These high-tech polymeric materials are often more economical and can help prolong the life of a structure.

Learn more about geosynthetic use in roads in “Using Geosynthetics to Improve Road Performance,” a summary of a decade-long study of two types of geosynthetics used in Minnesota highways. Find it at: <http://www.dot.state.mn.us/mnroad/reports/PDF's/Research Briefs Page/2011-20TS Geosynthetics.pdf>

in the sand greatly affects carrying capacity and negatively affects the experiment)

- 1 shovel (for shoveling sand into student buckets) (per entire group)
- Hand scoop, such as a large plastic cup (per team)
- 5-gallon bucket (per team)
- Scissors (1 pair per team)
- 5- to- 10-pound stackable weights, such as bricks, for testing wall strength (up to 150 pounds if possible) (per entire group)
- 2 wood boxes with removable bulkhead OR 2 of Really Useful Box® 8-Liter with hinged front (Office Depot Stock #452279) (per team)
- If using wood box:
  - 1 10-inch x 10-inch paper sheet for wall facing (for Wall #1) (per team)
  - 1 11-inch x 14-inch paper sheet for inclusion strips (for Wall #1) (per team)
  - Masking tape (10 inches) (for Wall #1) (per team)
  - Toilet paper (one 12-foot-long strip) (for Wall #2) (per team)
- If using plastic box:
  - 1 8.5-inch x 6.0-inch paper sheet for wall facing (for Wall #1) (per team)
  - 1 8.5-inch x 11.0-inch paper sheet for inclusion strips (for Wall #1) (per team)
  - Masking tape (6 inches) (for Wall #1) (per team)
  - Toilet paper (one 8-foot-long strip) (for Wall #2) (per team)



### Wood Box Building Instructions

#### Wall dimensions

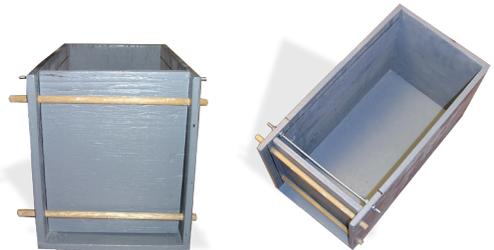
- side walls (2):
  - 16.5 inches (L) x 10.5 inches (H)
- back and front (bulkhead) boards (2):
  - 8 inches (W) x 10.5 inches (H)
- bottom board:
  - 9 inches (W) x 16.5 inches (L)

#### Rod dimensions

- all-thread rod: 1/4-inch diameter, about 11 inches long
- wood dowel rod: 1/2-inch diameter, about 11 inches long

#### Other materials

- 4 washers and 4 nuts to fit all-thread rod



Use the best 1/2-inch thick plywood you can find. Pre-drill the boards for the dowel and all-thread rod that will hold the front bulkhead. Dowel holes are about 1.75 inches from the top and bottom, and about 1 inch in from the front side. The all-thread rod is about a 1/2 from the top, and about 1 inch back from the dowel holes. The bulkhead will fit in place between the all-thread rod and the dowels.

Drill carefully to avoid splitting the wood. Glue the boards together. The side and back walls will sit on the top of bottom board; the bulkhead slides in and out between the dowels and the all-thread rod and also rests on top of the bottom board. Reinforce the glue with small wood screws placed about 2.4 inches to 3 inches apart. Set these while the glue is still wet.

When the box is completed:

- Draw a line 1-inch from the top around the interior three sides of the box. This will be the fill line.
- Draw lines on the top of each side wall 3 inches from the front edge. This is the line where the leading edge of the load will be placed.
- Draw a vertical line in front of the dowels all the way down the inside of the two walls. This is the line that represents failure if crossed by any part of the wall as loads are being added.



## Activity 5 (60 minutes)

### ① Icebreaker (5 minutes)

- Ask students if they have ever been driving or riding along in a car and noticed a wall built into the side of a highway. If so, what have they noticed about it? Where have students seen these walls? (They are often built along highways where a vertical slope needs to be constrained, or created to help secure and convey roads across challenging terrains. How high and wide are they? (They vary in height from about 4 feet to 100 feet high. Are there any structures above them? Tell students that these are called retaining walls.
- Point out to students that:
  - retaining walls are one of civil engineering's quiet superheroes. They are tasked with keeping the soil or rock in place behind the wall, and preventing down slope movement or erosion, as well as providing support for vertical or near-vertical grade changes.
  - retaining walls are designed and built to resist large forces, including constant pressures such as the weight of the wall, the pressure of the soil being retained, any weight (surcharge loads) on top of the wall, as well as periodic forces such as the weight of water when it rains or the forces of vibration due to earthquakes. In addition, retaining walls must often be constructed in challenging site conditions, including mountainous terrain, soft ground, and sites below water.

### ② Sand Wall Demonstration (5 minutes)

- Inform students you are going to build a soil retaining wall. Move sand into one of the boxes (but don't compact it very well).
- Ask students to predict how much weight they think the wall will hold. Ask students to provide their reasoning for their predictions.
- Now test the wall of sand for strength. Slowly stack the blocks on top of the unreinforced wall until the block tower tips over. (The wall is likely to fail as soon as the bulkhead is removed, prior to any load being added. This demonstrates a sharp contrast to how well students' walls will perform as a result of better construction techniques and simple engineering design principles).

### ③ Introduce Challenge (5 minutes)

- Inform students that they will now build and test their own reinforced soil walls. They will be creating miniature versions of a type of retaining wall called a mechanically stable earth wall (MSEW). Also known as reinforced earth walls, these walls represent cost-effective alternatives for many applications where reinforced concrete or gravity type walls have traditionally been used. One of the features of these types of walls that make them particularly effective is that the soil behind them is reinforced to make it stronger. Point out to students that soil beneath roadbeds can also be reinforced to add strength.
- Review the basic components of an MSEW:
  - It consists of reinforced earth with a facing wall. The reinforced earth typically consists of free-draining granular soil, spread out and compacted in layers.
  - The earth mass behind the wall facing is reinforced by placing tensile reinforcing elements (called inclusions) in the soil. Some examples of inclusions are steel strips, geotextile sheets, steel or polymeric grids, high-density polyethylene geogrids, steel nails, and steel tendons.
  - A wall facing is used to prevent soil from escaping out between the rows of reinforcement. Because a reinforced soil wall is inherently stable, the wall facing does not have to be particularly strong, and for this reason it is sometimes referred to as the "skin."
- Organize students into teams of three or four. Distribute the "Retaining Wall Challenge" student handout and other materials to each team (see Materials list for quantities). It is important that you supply no more than the amounts listed, as more of each material ensures greater reinforcement and lessens the importance of the design factor in the activity.
- Review the instructions on the handout with students prior to beginning the activity. Point out that the strongest wall wins as determined by how much load it can bear prior to failure. Note also that failure

will also be declared if any group violates the spirit of good sportsmanship, or breaks any rules.

#### ④ Design and Build (25 minutes)

- Let students know they will have 25 minutes to design, build, and test their walls. Periodically remind students of passing time so they continue to make steady progress.
- Have students sketch out an initial design for each of their two walls. Direct students' attention to the materials list and building instructions on their handouts that defines the amount and use of each materials for each wall. (Point out to students that making the toilet paper wall design needs to support the wall face from top to bottom [no computer paper can be used]).
- Walk around and monitor students' progress as they build their structures. Make sure teams are careful about not applying too much pressure to the soil (surcharge load) as they compact the soil. Try not to direct students' too much in their design. Everyone will learn later from both the successes and failures.

#### ⑤ Test the Walls (10 minutes)

- Supervise students as they apply the weights slowly and incrementally. (Weights should be placed on the leading edge of the load 3 inches from the front of the wood box). Stop the loading if the stacked weights are becoming unstable.
- The winning design is the one that bears the most load prior to failure. Failure is declared when any portion of the wall system (including paper, tape, and reinforced soil) crosses a vertical plane defined by the lines drawn through the front edge of the dowel holes. It is OK if a bit of sand leaks out around the sides as long as it stops after about 10 seconds and it is only a relatively small amount of sand. A winning design will be chosen for each of the two types of reinforcement strategies.
- The two different wall simulations are very simplistic representations of two wall schemes used in retaining wall design: the toilet paper wall is an example of a wall scheme that uses geosynthetic fabric, while the paper-reinforced model represents a wall designed with steel or grid strip reinforcement.
- A similar experiment once held more than 150 pounds! If students' boxes don't reach failure, take the opportunity to point out how much the wall(s) held out and was able to bear as much weight as was available to test it.

#### ⑥ Share Results (5 minutes)

- Have the winning team(s) share their design(s) and ask team members to discuss why they think their design supported the most amount of weight.
- In addition, review the other designs and discuss why students think that they didn't support as much weight as the winning design. You may want to take this opportunity to note to students that engineers learn a lot from designs that don't perform optimally—sometimes more than from the ones that work well right away! Some common causes of failure or poor performance include:
  - failure at the connection of the tie to the wall facing
  - ties that are too short
  - tie vertical spacing that is too large
  - not enough ties in the heavier stressed area near the bottom of the wall
  - damage to ties during backfilling and construction
  - too little flange around the sides resulting in excessive leakage (Note that too much flange folded around the side could have added resistance that was not due to the reinforcement strategy).

#### ⑦ Wrap Up (5 minutes)

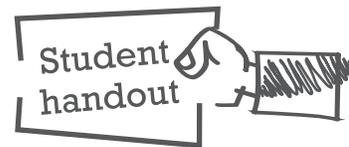
What do students think would happen if wet sand were used instead of dry sand in this experiment? For example, what happens when you add water to sand to build a sand castle? (Moisture in the sand will greatly increase the carrying capacity of the wall and makes the walls stronger.) When walls fail or move excessively it is often because of pore drainage. Why do students think this happens? (Water pressure builds up behind a wall and exerts additional forces the wall may not be able to sustain. This is why engineers avoid backfilling walls with clay-like soils that hold a lot of water.



## Extensions

- **Dig into learning more about soil.** Learn about soil composition, soil chemistry, soils and land development, and more with these K–12 lessons from the Soil Science Society of America. Find them at: <http://soils4teachers.org/lessons-and-activities>
- **Investigate types of retaining walls.** The mechanically stabilized earth wall profiled in this activity is just one type of a retaining wall (it is a type of gravity wall). Engineers also build other types of retaining walls, including concrete cantilevered and anchor walls. Assign students (or teams) a type of wall to research, and have them prepare a five-minute PowerPoint presentation that explains how the wall retains soil and rock, ways that the wall can be built, and photos of the walls.
- **Explore geosynthetics and how they work.** Geosynthetics are made from polymeric materials, and are used in a number of different applications. Have students investigate this materials science field. What kinds of geosynthetics are there? Who uses them and for what? Specifically, how are they used in the construction industry? What advantages do they have over more traditional materials? What are the disadvantages to using them?

# Retaining Wall Challenge



**Your Challenge:** Design and build two small-scale mechanically stabilized earth walls with different reinforcement strategies, and load them to failure.



## Construct It!

- Place the sand in layers and pat in place with your hand. No compaction devices are permitted. Do not stand on, kick, pound, or hit the sides of the box with your hands or feet. Do not lift the box by the all-thread rod.
- Follow the instructions below for each wall.

Wall #1
<ul style="list-style-type: none"> <li>• Construct Use the 10-inch x 10-inch (or 8.5-inch x 5-inch) sheet of paper for the wall facing. Fold a small portion around the sides of the box.</li> </ul>
<ul style="list-style-type: none"> <li>• Construct Use scissors to cut strips of paper from one 11-inch x 14-inch (or 8.5-inch x 11-inch) sheet of paper. The reinforcing strips should be sandwiched between layers of sand.</li> </ul>
<ul style="list-style-type: none"> <li>• Construct Use masking tape to attach the reinforcing strips of paper to the back of the wall facing only. Tape cannot be attached to the box or any parts thereof or used as reinforcement.</li> </ul>
<ul style="list-style-type: none"> <li>• Construct the reinforced earth mass by placing alternating layers of sand and reinforcing strips.</li> </ul>
<ul style="list-style-type: none"> <li>• Fill the box up to about 1 inch below the top.</li> </ul>

Wall #2
<ul style="list-style-type: none"> <li>• Before starting, make sure your design will support the wall face, from top to bottom (no wall facing paper is permitted for this wall)</li> </ul>
<ul style="list-style-type: none"> <li>• Fold the strip of toilet paper around (encapsulating) each layer of sand.</li> </ul>
<ul style="list-style-type: none"> <li>• No tape is permitted for this wall.</li> </ul>
<ul style="list-style-type: none"> <li>• Construct the reinforced earth mass by placing alternating layers of sand and reinforcing strips.</li> </ul>
<ul style="list-style-type: none"> <li>• Fill the box up to about 1 inch below the top.</li> </ul>



## Materials:

- Dry sand
- Hand scoop
- 5-gallon bucket
- Scissors
- 5- to- 10-pound stackable weights, such as bricks, for testing wall strength
- 2 boxes with removable bulkhead, either wooden or plastic
- **If using wood box:**
  - 1 10-inch x 10-inch paper sheet for wall facing (for Wall #1)
  - 1 11-inch x 14-inch paper sheet for inclusion strips (for Wall #1)
  - Masking tape (10 inches) (for Wall #1)
  - Toilet paper (one 12-foot-long strip) (for Wall #2)
- **If using plastic box:**
  - 1 8.5-inch x 6.0-inch paper sheet for wall facing (for Wall #1)
  - 1 8.5-inch x 11.0-inch paper sheet for inclusion strips (for Wall #1)
  - Masking tape (6 inches) (for Wall #1)
  - Toilet paper (one 8-foot-long strip) (for Wall #2)



## Test it!

- Open the front of the box.
- Apply the weights (known as surcharge loads) slowly and in increments. Place the leading edge of the load 3 inches from the front of the box.
- Failure is declared when any portion of the wall system (including paper, tape, and reinforced soil) crosses a vertical plane defined by the lines drawn through the front edge of the dowel holes. (Failure will also be declared if any group violates the spirit of good sportsmanship, or breaks any rules.) It is OK if a bit of sand leaks out around the sides as long as it stops after about 10 seconds and it is only a relatively small amount of sand.
- Determine the maximum load carried by the wall prior to failure.
- The group that supports the largest cumulative load wins!

Team: \_\_\_\_\_

	Load (lb.)
Wall #1 (reinforcing paper strips)	
Wall #2 (toilet paper reinforcement)	



## Connecting to the World

### Under Pressure!!!

Think you're under a lot of pressure? Think again. Consider what a retaining wall has to put up with: pressure from the soil backfill and any additional soil on top of the wall itself, the burden of water when it rains, and the possibility of additional loads from vehicles scurrying back and forth over the top of the backfill or even vehicles parking right on top of the wall. And if that weren't enough, it has to be designed to stay up when the Earth itself starts to quake.



Photo Courtesy of ADSC.

That's one tall order. Particularly tall, in fact, for one very special wall being built at India's Pakyong Greenfield airport in Sikkim. Its job description is the same as any other retaining wall: restrain the soil and rocks behind it. But coming in as one of the tallest retaining walls in the world (262 feet high), that's a lot of restraint.

The Pakyong airport wall is reinforced with horizontally laid geosynthetic grids sandwiched between layers of compacted backfill. The slopes are covered with a vegetated mesh soil retaining system that encourages plant regrowth.

The building of this wall was made possible due to geosynthetics (products manufactured from a polymeric material). For more about different types of geosynthetics used in construction, see:

<http://www.betterroads.com/down-to-earth-2>

# Make it Real, Make a Difference



## Make It Real

Extend your students' exploration of transportation with any of these speaker presentations, field trips, and community service projects.



### Speakers

**Invite an engineer from your city's transportation division** to discuss the kinds of projects the city does. Let the speaker know what the students have been, or will be learning about through the transportation module's activities: types of streets, including Complete Streets; traffic counts; left-turn lane design; how projects are staged; and soil reinforcement. You might want to suggest that the speaker describe the kinds of the projects the city undertakes throughout the year. Some questions to address might include:

- What is a typical week like for a city transportation engineer? How much time is spent in the office vs. in the field?
- What tools do you work with? (If possible please bring tools, drawings, models, or other show-and-tell objects.)
- What other kinds of professionals do you regularly work with?
- Can you describe how traffic studies are done, including how they are initiated, what kind of data is collected, and how the data informs decision-making?
- If the city has a Complete Streets policy, please describe when the policy was initiated and what the current plans are to design and implement Complete Streets in various parts of the city (bring any written information you might have about the policy, and renderings for Complete Streets projects if available).
- How did you get interested in engineering? What do you like most about your job?

### Invite a volunteer from Engineers Without Borders to speak about civil works

**projects.** Engineers Without Borders (EWB) supports community-driven development programs worldwide through partnerships that design and implement sustainable engineering projects. Project types include water supply, sanitation, civil works, structures, energy, agriculture, and information systems. One EWB chapter built a road and drainage project in Las Pilitas, El Salvador, linking one section of the community to a more populated and resourced area. To find a local EWB chapter, search for "Student Chapters" at <http://www.ewb-usa.org/chapters/locate-chapter>. See each chapter's page for a list of current projects related to transportation.

**Bike clubs** can sometimes arrange to have representatives visit organizations to provide tips for how to ride a bike in a city environment, review bike safety, and more.



### Field Trips

**Tour a traffic management center.** Traffic management centers monitor traffic and identify problems, use data to get a real-time picture of traffic conditions, coordinate emergency and disaster responses when needed, and more. Some tunnel systems are also monitored by a management center. Contact your local center to see if a tour can be arranged.

**Visit a transportation construction site.** A construction site shows engineering in action. Contact your local city engineers or state department of transportation engineers to help arrange a visit. Some factors to consider before you go:

- Verify the name of the person who arranged permission, a field contact, and where to report.
- Secure parent permissions, if needed.
- Have your contact provide reduced plans or a general layout of the site if possible so you

can get acquainted with the site prior to visiting.

- Call your field contact prior to the visit to ask what safety equipment is required, and if you can borrow the necessary materials at the site in the amount you need before you go.
- Ask your contact what other arrangements should be made prior to the visit.
- Consider having students bring earplugs in case it is noisy.
- Remember to bring the phone number of your contact in case you can't find the main contractor trailer.
- When you arrive, park where you are not blocking anyone and check in with the general contractor's office.
- Make sure students stay with the group. Remind them to watch where they step, to be sure stay clear of any powered equipment, and to read and obey all signage they see.

**Join a biking tour of your city.** Bike clubs often offer free tours of the city for bicyclists of all levels. A biking tour would allow students to see their city from a biker's perspective and assess how bike-friendly various areas of the city are or are not.



## Make a Difference



### Community Service Projects

**Get involved with your local biking group.** Many communities have active biking groups that work to enhance bicycling conditions in their own communities or to increase bike ridership in the area. Biking organizations may offer information on how community transportation policies are made, best ways to advocate on behalf of bicyclists, information on the positive impact that bicycling can have on a community's health, and more. Biking groups often need volunteers to help recruit new members, staff events, or provide office support.

**Check out transportation programs for seniors.** Some seniors want to live in their homes as long as possible but at some point can no longer drive and need to find ways to get places such as the doctor's office, grocery store, and more. See what kind of transportation options your city offers for seniors who can no longer drive, and check to find out if there are ways students can help (e.g., by participating in a program if they have a driver's license or doing advocacy work to increase transportation options for seniors).

# Additional Resources

## **Greatest Engineering Achievements of the 20th Century**

<http://www.greatachievements.org>

Click on “Highways” for a timeline and information about the scientific and engineering breakthroughs that have led to the nation’s vast network of roads, bridges, and tunnels. (National Academy of Engineering)

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## **NEA Grand Challenges of Engineering: Restore and Improve Urban Infrastructure**

<http://www.engineeringchallenges.org/cms/8996/9136.aspx>

Learn about the current state of the nation’s infrastructure, how it is maintained, and ways it could be improved. (National Academy of Engineering)

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## **Report Card for America's Infrastructure**

<http://www.infrastructurereportcard.org>

Click on “Infrastructure by Category” to find the latest report card for America’s roads, bridges, waterways, rail, and transit systems. (ASCE)

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## **Highway Functional Classification Concepts, Criteria and Procedures (2013 Edition)**

[http://www.fhwa.dot.gov/planning/processes/statewide/related/highway\\_functional\\_classifications/fcauab.pdf](http://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/fcauab.pdf)

Describes the procedures and processes for assigning functional classifications to roadways. Provides additional classification categories to arterials, collectors, and locals to describe these functions more precisely. Real-world examples are presented to help make the discussion of functional classification more readily understood.

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## **American Association of State Highway and Transportation Officials**

<http://www.transportation.org/Pages/Default.aspx>

Find news related to roadways and vehicles, infrastructure, freight, safety, and more. Publishes technical reports including the Roadside Design Guide and A Policy on Geometric Design of Highways and Streets.

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## **Intersection Safety**

<http://safety.fhwa.dot.gov/intersection>

Over the past several years, an average of 21 percent of the fatalities and roughly 50 percent of the serious injuries have been attributed to intersections. This Federal Highway Administration site provides information about alternative intersection design, proven safety countermeasures, and more. (FHWA)

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## **Benefits of Access Management**

<http://safety.fhwa.dot.gov/geometric/pubs/accessmgmtbrochure/index.htm>

Access management is a set of techniques used to control access to highways, major arterials, and other roadways. This brochure outlines the benefits of several techniques, including access spacing, turning lanes, and median treatments. PDF version at [http://ops.fhwa.dot.gov/access\\_mgmt/docs/benefits\\_am\\_trifold.pdf](http://ops.fhwa.dot.gov/access_mgmt/docs/benefits_am_trifold.pdf) (FHWA)

### **From Plans to Pavement: How a Road Is Built**

<http://www.michigan.gov/mdot/0,1607,7-151-9615-129011--,00.html>

Explains the steps in a typical road-building project. Includes an extensive glossary of road terms. (Michigan Department of Transportation)

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### **Building with Reinforced Soil**

<http://www.agf.gov.bc.ca/resmgmt/publist/600Series/644000-3.pdf>

This fact sheet describes the use of geosynthetics, welded wire mesh, and compacted soil layers to construct walls, box culverts, and bridge abutments. Includes information on what geosynthetics are, and photos and diagrams of basic reinforced soil components. (British Columbia Ministry of Agriculture and Lands)

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### **Soils Magic book** by David J. Elton. Geotechnical Special Publications 114: ASCE, 2001.

The experiments in this 72-page book reveal the nature of soil through educational outreach activities, from turning soil into a fluid to making water flow uphill. Intended for K–12. An accompanying CD-ROM provides videos of each experiment. (ASCE)

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### **Better Roads Magazine**

<http://www.betterroads.com>

Provides articles on a number of topics, including news, business, products, and safety about highway, road, and bridge construction; management; maintenance; repair and rehabilitation; and winter maintenance. Technology section includes articles about road science, better bridges, and applications and innovations in the field. (Randall-Reilly Publishing Company)

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### **The Future of Transportation**

<http://www.citylab.com/special-report/future-of-transportation>

Articles from The Atlantic's CityLab reporting on transportation issues in metro areas and neighborhoods, including infrastructure, mass transit, parking, and more. (The Atlantic Monthly Group, Inc.)

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### **Go! Exploring the World of Transportation**

<http://www.go-explore-trans.org>

Written by high school and college students, as well as transportation professionals, this online magazine provides a forum for learning about transportation and transportation careers. The magazine showcases such topics as infrastructure, vehicles, designers, and users of transportation. The site also includes information on scholarships, internships, and other educational resources. (Iowa State University, Institute of Transportation)

# Credits

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