MODULE 5: SUSTAINABLE AND INTELLIGENT TRASPORTATION TECHNOLOGY

LESSON 1: SUSTAINABLE TRANSPORTATION TECHNOLOGY

GRADE LEVEL: 6 - 8

Transportation vehicles – cars, trucks, buses, trains – consume a substantial percentage of our limited environmental resources. Intelligent Transportation Systems (ITS) can potentially reduce total resource consumption through the use of programmed travelling patterns that minimize fuel-inefficient commuting routes, and maximize large-scale multimodal system use. Students will investigate ITS-based solutions for reducing fuel consumption and calculate their carbon footprint.

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Lesson 1: Sustainable Transportation Technology

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Grade Level: 6 - 8	**Lesson in this Module:** 1 of 1
Time Required: 90-120 minutes	**Lesson Dependency:** None
Keywords: Sustainability, Carbon Footprint, Traffic Congestion, Congestion Pricing, Ramp Metering, Connected Vehicles	

Related Curriculum

Subject Areas	Science; technology; engineering; mathematics
Curricular Units	Intelligent transportation systems
Activities	Research of Sustainable Transportation Systems; Trip Calculations using Multi-Modal Transportation Systems

Educational Standards

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

Pre-Requisite Knowledge

None.

Learning Objectives

- Students will recognize the need for sustainable transportation solutions.
- Students will investigate ITS-based solutions for reducing fuel consumption.
- Students will calculate costs for transportation given pre-determined trip scenarios, or those supplied by instructor, using provided and/or researched information on multiple modes of transportation.
- Students will also calculate the carbon footprint of the trip and compare their trip to other trips where different types of vehicles or modes were used for travel.

Introduction/Motivation

The idea behind this STEM lesson is that transportation vehicles – cars, trucks, buses, trains – consume a substantial percentage of our limited environmental resources. The motivation here is that Intelligent Transportation Systems (ITS) can potentially reduce total resource consumption through the use of programmed travelling patterns that minimize fuel-inefficient commuting routes, and maximize large-scale multimodal system use. Analysis and hands-on student activities will help reinforce these ideas.

Lesson Background & Concepts for Teachers

Transportation is the second largest expense for American households, costing more than food, clothing, and health care. The vast majority of this money, nearly 98 percent, is for the purchase, operation, and maintenance of automobiles. Drivers spent $186 billion on fuel last year and Americans will spend an estimated $260 billion in 2020.

Sustainability

Sustainability is the practice of living in a way that can provide the necessary goods and services for both humans and the natural world without compromising the availability of resources for either party in the future.

Attempting to live in a way that allows future generations to experience the same quality of life is not a new concept and is based on an abundant supply of resources. However, resources are projected to be scarce in the future as a result of our present rate of consumption. Therefore, we

must learn how to use resources efficiently in order to sustain our current lifestyle.

The concept of sustainability has likely been around throughout human history; however, one of the first documented cases was Carl von Carlowitz. As described in the video on sustainability shown in Activity 2, Carl von Carlowitz made the case for planting as many trees as are being cut down, in order to avoid an energy crisis.

One way of looking at sustainability is through the three pillar method. The three pillars are: environment, economy, and social perspectives. The sections below describe how each of the three pillars relates to transportation.

> Included under the **environment pillar** are long-term climate impacts and resource availability. The types of materials we use can impact the environment; however, not all materials will impact the environment equally. Research within the area of sustainable materials has increased greatly in the last century, and as a result, we are able to make informed decisions on which materials to use, and how they will affect the environment. Other topics included in the environmental pillar include: biodiversity, eating organic food, and pollution.
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> The **economic pillar** is closely tied with the environment pillar. If resources are not immediately available in one location, they must be transported there from their native habitat. For example, the United States does not produce enough oil to serve the needs of everyone in the country. Therefore the United States purchases oil products from overseas and pays to transport them. Not only does this cost money, but it also utilizes a variety of resources in order to transport the oil. Since fossils fuels still make up a significant amount of the energy required to meet this need, there is a serious environmental consideration that results from this economic decision.
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> The **social perspective pillar** relates to how human interaction impacts sustainability. This pillar mostly pertains to ensuring that everyone is treated fairly in a sustainable world with focus on balancing the needs of the individual with the needs of the group. For example, when a wealthy or powerful country like the United States experiences an unusually high demand for coal which they cannot satisfy, they end up purchasing the extra needed coal from other countries, which deprives that country of the ability to use that resource. Another aspect of the social perspective is ensuring that one country's lack of socially-conscious pollution limitations does not cause health issues in neighboring lands.

By using environmentally friendly, local, non-polluting, renewable resources, we can respect each other's rights and create a cleaner world for all of us.

Fossil Fuels

Fossil fuels, such as coal and oil, are the world's primary energy source. Coal alone provides more than half of the electrical power in the United States. The demand for coal and oil has increased tremendously since the invention of automobiles and air transportation, but the process required to

mine and use this fuel source has negative effects on our environment. Drilling for oil used to primarily take place on land, but has since moved to the ocean floor to collect additional resources.

Fossil fuels are used in almost every form of transportation. Most vehicles use processed oil, commonly known as gasoline, to power the combustion engines in their cars. Even cars with electric engines use household energy (generated from burning coal) to re-charge their batteries.

Carbon Footprint

A carbon footprint is an estimated measurement of the amount of CO_2 (greenhouse gas) that an average individual, family, or company emits into the atmosphere over a given time period (day, month, year, etc.). Personal vehicle transportation accounts for almost half of a family's annual CO_2 emissions. Other indirect transportation costs, such as transporting food and goods to stock supermarket shelves, could account for an additional 10% of a family's total carbon footprint. Another major contributor includes air transportation (the fastest growing contributor to greenhouse gas emissions).

Annually, the United States emits 7 billion tons of $C0_2$. Over one quarter of that is attributed to transportation systems. Breaking it down even further, light vehicles (such as cars, vans, pickup trucks, etc.) account for 60% of the total carbon footprint of transportation. Following light vehicles are trucks, air transportation, water transportation, rail transportation, and buses. While the distribution is heavily biased towards the popularity of each mode of transportation, some modes of transportation are more energy efficient and environmentally responsible than others.

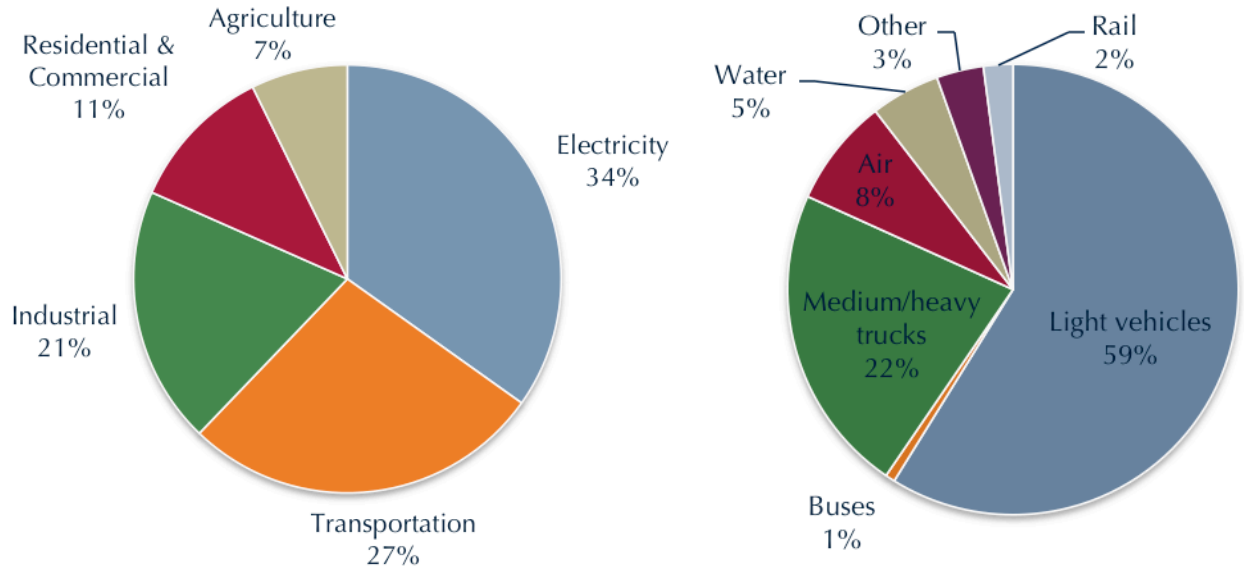

Figure 1: Distribution of U.S. Greenhouse Gas Emissions (http://www.c2es.org/energy/use/transportation)

Traffic Congestion

The last tab of the Web Quest prompts students to read a news article about the effects of traffic congestion and to answer the following questions. Below each question is a set of suggested answers.

1. What are the 5 effects of traffic congestion the article mentions?
   Delay, inability to estimate travel time, fuel consumption and pollution, road rage, emergency vehicle navigation

2. Think of a way that traffic congestion affects environmental sustainability?
   When vehicles are constantly in stop and go traffic, they travel at slower speeds which are much less energy efficient than traveling at higher speeds. This increases the amount of greenhouse gas emissions and increases a vehicle's fuel consumption. Recent developments in hybrid vehicle engines make use of innovative technologies that capture regenerated energy upon breaking in order to reduce fuel consumption and cut down on harmful emissions.

3. Think of a way that traffic congestion affects economic sustainability?
   By drilling oil below the ocean floor, the cost of transporting oil is high. Additionally, a lot of the oil that the United States uses is purchased from the Middle East. When buying goods overseas, the goods are usually subject to a variety of expensive taxes, thus increasing the overall price of the product.

4. Think of a way that traffic congestion affects social sustainability?
   Social sustainability can be achieved by ensuring affordable transportation for all levels of income. When one mode of transportation is extremely congested (for example, personal cars), people can choose to travel by other modes such as using a local bus or train system.

Using ITS to Improve Sustainability

Intelligent Transportation Systems (ITS) can improve sustainability in many ways.

EZ-Pass tollbooths are an example of ITS helping to conserve vehicle emissions as a way of contributing to sustainability. These automated systems recognize a piece of hardware attached to a vehicle called an "EZ-Pass" which has an electronic signature that can be picked up by and EZ-Pass compatible toll booth. The EZ-Pass allows for an instant electronic payment transaction, linked to a credit or debit card, which is both convenient for the driver and helpful to the environment because it allows the vehicle to stay in motion rather than come to a full stop. This improves the efficiency of the roads as well as the fuel economy of individual vehicles.

Along similar lines, some large cities that experience a lot of congestion have begun implementing congestion pricing along toll roads. The concept of congestion pricing relates to the economic principle of supply and demand. When traffic is expected to be heavy, such as during morning or evening rush hours, toll road authorities charge a higher fee to drive on the road. Some people who do not wish to pay the higher fee may opt to drive alternate routes or drive at a time when the fees are cheaper. In this way, the system is able to reduce the number of cars on the road, thus improving the flow of traffic, and reducing the pollution and greenhouse gases that were emitted during a standard rush hour.

On congested non-toll roads, some State agencies have implemented a system called ramp metering. Ramp metering is a system that limits the number of vehicles that can enter a highway within a certain

timeframe. The system intends to reduce congestion by keeping traffic moving at a steady speed. For example, if a steady line of ten cars attempts to merge onto a busy highway at the same time, traffic will back up because there is not enough room for all the vehicles to merge at once. Cars will end up applying brakes and swerving into other lanes just to provide room for the new vehicles. Ramp metering systems will break up this line of vehicles by only allowing one vehicle through every few seconds. This method essentially spaces the new vehicles at intervals that are easy to merge with the existing traffic flow on the highway. Implementation of ramp metering systems has proven to improve traffic flow and reduce the number of crashes.

New technology, called connected vehicles (CV), allows software programs inside of vehicles to identify the presence of other vehicles and determine the safest and most efficient way to guide vehicles through the intersection. It has the potential of improving sustainability by reducing the amount of fuel consumption. For example, imagine there are two small vehicles, one bus, and one tractor-trailer truck approaching a 4-way intersection at the same time from different directions. In today's world, two of the vehicles would be required to stop at a red light, while the other two receive a green light. If the cars' CV software is programed to value overall fuel efficiency (crash avoidance is assumed), it can allow the vehicle with the worst fuel efficiency (the tractor-trailer truck) to go straight through the intersection without stopping or slowing down. The other vehicles may be instructed to slow down just enough to allow them to pass through the intersection right after the truck. This results in an overall reduction of fuel consumption.

Another way to improve sustainability is to encourage road users to reduce their carbon footprint. One method of doing this is to utilize environmentally friendly modes of transportation such as walking or riding bicycles. While walking and biking may not be effective for all trips, metro/bus systems, carpooling, and ridesharing can also provide fuel efficient methods of transportation. Some cities have built special bus-only lanes on congested roads to entice more people to utilize bus systems. Similar to CV technology, providing bus-only lanes reduces congestion in that lane and reduces the amount of fuel that a bus would typically need to spend in stop-and-go traffic.

Background for Activity 3

A Brief Background on Microsoft Excel and Google Maps.

Microsoft Excel is a multi-faceted tool in the Microsoft Office suite. For this activity, students will use Excel's ability to program equations and perform calculations given certain values.

Students will complete tables that calculate the cost and environmental impact of a trip from one point to another. At this level and to save time, students can either be assigned or draw a trip scenario from a hat. Each scenario will have an occupation for the traveler and a trip described from one city to another. The total trip miles are listed with a break-down of miles for each segment of the trip. For example, the student might be a nurse and drive to the closest bus station and take a commercial bus to the destination city station, but then walk to their final destination which could be a hospital for a job interview. The student will decide what type of vehicle to take for the trip. Although the student may decide to walk the entire trip to reduce their carbon footprint, this is not a practical approach, since the

cost of their trip will include their time spent to take the trip. Once calculations are complete, students can discuss and compare trips and if time allows, perform calculations using alternate transportation modes.

Alternatively, students could use Google Maps to select their own route and modes of transportation needed, based on instructor input. Google Maps is a quick tool which would allow students to choose from various modes of transportation such as driving, walking, riding a bicycle, or taking public transportation. Using the information provided in the Lesson Plan documents, students also be asked to optimize their trips in terms of cost and environmental impact.

Google Maps is an online resource provided by Google Inc. which allows users to map routes using satellite imagery. Completely free, this program has been refined over the last few years to be able to include Street View, which shows an actual panoramic picture of an area a user decides to view. These full-panoramic (360 degree) pictures can be cycled through by clicking along the direction of any of the roads, recreating the experience of walking on the street. This allows users not only plan their trips from the bird's eye view perspective, but also at street level view.

Vocabulary/Definitions

Vocabulary Word	Definition
Intelligent Transportation Systems	Advanced technologies that transportation engineers use to improve transportation safety and traffic flow. In this module, actuated or semi-actuated traffic signals represent one form of intelligent transportation systems.
Sustainability	Practice of living in a way that can provide the necessary goods and services for both humans and the natural world without compromising the availability of resources for either party in the future.
Biodiversity	The range of organisms in a defined ecosystem, or the genetic variation within and between species.
Fossil Fuels	Nonrenewable, combustible organic material, as oil, coal, or natural gas, derived from the remains of former life and used as an energy source.
Carbon Footprint	Estimated measurement of the amount of CO_2 (greenhouse gas) that an average individual, family, or company emits into the atmosphere over a given time period (day, month, year, etc.).
Congestion Pricing	Varying the price of tolling stations in order to incentivize a percentage of drivers to find another method of travel. This helps reduce congestion on overcrowded roads.
Ramp Metering	A system that limits the number of vehicles that can enter a highway within a certain timeframe. Used on congested, non-toll roads.

Connected Vehicles	Technology inside vehicles used to identify the presence of other vehicles and determine the safest and most efficient traffic flow patterns.

Associated Activities

- **Activity 1 – Web Quest (20-30 minutes)**
  Based on student background, consider starting with this activity.
  http://sustainabletransportationintro.weebly.com/
  Students will gather information by following a series of links to identify the environmental impacts of today's cars. Topics include:

  - What is sustainability?
  - What is a fossil fuel and how does its consumption impact our environment?
  - How has vehicular consumption of fossil fuels changed over time?
  - When do vehicles consume the most fuel or the least fuel?
  - How does traffic congestion affect fuel consumption?

- **Activity 2 – Group-work to Research Sustainable Transportation Systems**

  - Assign students to groups to research one of the following topics:

    - Tollbooth EZ-Pass
    - Congestion pricing
    - Ramp-metering systems
    - Adaptive signal control
    - Multi-modal transportation

  - Discuss in class how these technologies or designs reduce traffic congestion, vehicle emissions, and fuel consumption.

- **Activity 3 – Sustainable Transportation Challenge using Multi-Modal Transportation Systems**

  - In advance, the instructor may look into the modes of transportation available in their area and discuss any modes listed on the attached spreadsheet which students may not be as familiar with.

  - Based on the number of students and available Trip Scenarios (there are only 4 included with this lesson) divide into small groups and determine the following parameters in order to start the trip:

    - Type of vehicle to start your trip
    - Your occupation as a traveler

- Calculate the total transportation costs and total carbon footprint for different types of consumers using different modes of transportation. Use the trip scenarios included in this lesson and the worksheet to perform the calculations.

- If you do not want to use a predetermined trip, create your own trip or ask the students to create a trip and use the Web to search for information required in the highlighted fields on the Excel spreadsheet. Examples might include: estimate the cost of making a typical trip in your schedule (travel to school), traveling to a vacation destination, and traveling to an interview in a metropolitan area. Using the Reference Tables in the spreadsheet, determine your transportation mode and the mileage for that mode. Once the information it entered into the cell, the calculations will be automatically performed. Follow these steps:

    1. Map out a trip and determine miles to be traveled for each selected mode using internet tools such as Google Maps (blue-shaded field).
    2. Research the average fuel costs for your area of travel (gray-shaded field)
    3. Search this website link for a chosen occupation's **Mean Hourly Wage** under State Occupational Employment and Wage Estimates in VA: http://www.bls.gov/oes/current/oes_va.htm#39-0000 (green shaded field). Some examples of pay rates are listed in the Reference Tables in the spreadsheet.

- Take away experience for this activity: Although the attached spreadsheet includes formulas to perform the necessary calculations, students can practice calculating gas mileage for their own family vehicles by following these steps:

    1. Fill the vehicle's gas tank until it is completely full.
    2. Write down the mileage on the odometer, or if your vehicle has a trip meter, reset it to zero prior to leaving the gas station.
    3. When at least half of the fuel has been consumed, refill the tank and write down the amount of gallons it took to fill your tank.
    4. Record the mileage on the odometer and subtract the first odometer reading to get the miles traveled, or write down the miles on the trip meter
    5. Divide the number of miles traveled by the gallons of gas to get the miles per gallon (mpg).
    6. Compare this value with the estimated mpg that the car manufacturer listed for your vehicle, if available.

To inspire students to do this at home, an example may be performed using a teacher's vehicle or even compare gas mileage and carbon footprint of different vehicles belonging to school personnel.

Guidelines for this calculation are here: http://www.fueleconomy.gov/mpg/MPG.do?action=calcMPG

Lesson Closure

- Discuss the value of ITS for reducing fuel consumption. Specific ITS-related examples for reducing fuel consumption include:
  - Tollbooth EZ-Pass
  - Congestion pricing
  - Ramp-metering systems
  - Adaptive signal control
  - Multi-modal transportation

Attachments

- Weebly Web Quest: http://sustainabletransportationintro.weebly.com/
- Multi-modal Transportation Reference Tables and Calculation Table in Excel
- Activity 3 Worksheet

Extensions/Multimedia

- Utilize Edmodo (www.edmodo.com) to provide further questioning and discussion between students and teacher. Edmodo is a safe, social learning website made specifically for teachers and students. It is a way to collaborate on assignments, homework, projects, and after-school STEM programs and is used as a communication tool to provide additional questioning and feedback from teachers and students.