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Petros J. Katsioloudis
Old Dominion University, pkatsiol@odu.edu

Mildred V. Jones
Old Dominion University, mjones@odu.edu

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By Petros J. Katsioloudis and Mildred V. Jones

The transportation industry and consumers alike are concerned about the environment, energy resources, efficiencies, and economics.

Transportation is without a doubt one of the biggest contributors to the destruction of our environment. We have seen decades of evolution in the transportation industry since the Industrial Revolution began (1820-1870). The Industrial Revolution produced machines, factories, and transportation transformed by technology and the discovery of electricity, as well as process development in factories where we accelerated production lines and the way goods were produced. Today, it is the evolution of technology and transportation that allows us to enjoy fresh fruits and vegetables in winter, receive packages overnight from anywhere in the world, and have Christmas presents delivered to our door just in time for the holiday. It is also our vast intermodal transportation network that allows us to compete in world markets with exports and imports from more than 200 countries across the globe. Our transportation system has become vital for maintaining our economy and allowing us to compete in world markets. "The United States is the world's largest economy and leading importing nation, accounting for 23 percent of world gross domestic product (GDP) and 13 percent of the value of the world merchandise imports in 2008" (U.S. Department of Transportation, 2010).

Results from environmental research and pursuant governmental regulations are changing the way companies do business and how our transportation systems address the future. The Environmental Protection Agency (EPA) has been at the forefront in leading environmental research and instituting policies and regulations to fight the issues impacting our environment. We have heard for many years that our environment suffers from human impact. The transportation industry is one human factor that has had a significant impact on our environment, from shipping containers by sea on ships, trucks on our highways, planes in the air, oil through

pipelines, to the trains that travel over land via the railway system. And yes, automobiles too! We have invaded the natural environment without regard to what the real costs to human survival may be, until now. According to a report prepared for the Pew Center on Global Climate Change (2003), trucking accounts for "72 percent of transportation energy and carbon emissions, with air transport [coming in second at] 10 percent, followed by marine, rail, and pipeline" (Green & Schafer, 2003).

Shipping

The shipping industry has been a big target of the EPA, focusing on the diesel engines that power the ships. Shipping is considered to be as much of a contributor to pollution as aircraft. Shipping may perhaps be the most efficient method of transportation, so it is vital that we address its impact on our environment.

There are two types of diesel engines used to power large ships: *main propulsion* and *auxiliary*. The EPA classifies these engines as "Category 3" marine diesel engines. Typically, propulsion engines can be as large as three stories tall and be as long as two to three school buses. Auxiliary engines, on the other hand, are much smaller, ranging in size from small, portable-type generators to "locomotive-size" (Environmental Protection Agency, 2011).

Sulphur pollution may be the biggest pollutant coming from the shipping industry: "…just 16 of the world's largest ships can produce as much lung-clogging sulphur pollution as all the world's cars" (Pearce, 2009). It is estimated that the largest ships can release up to 5,000 tons of sulphur annually as well as a billion tons of carbon dioxide (CO_2). University of Delaware professor James Corbett is an expert on ship emissions. Corbett estimates that the death toll globally could be as much as 64,000 annually, with 27,000 in Europe alone. He believes that Britain is likely the hardest hit, with about 2,000 deaths annually (Pearce, 2009).

The International Maritime Organization (IMO) oversees the world's shipping industry. In 2008, the IMO mandated that fuel for shipping "should not contain more than 3.5 percent sulphur by 2012, and eventually must come down to 0.5 percent. This figure could halve the deaths," says Corbett. However, approximately two-thirds of the world's ships are operated by developing countries (i.e., Panama) that say they cannot afford the costs associated with such reductions. Yet, we are looking at carbon emissions tripling by 2050 if new parameters are not set to reduce such pollution caused by the shipping industry (Pearce, 2009). However, these regulations are attracting the attention of some companies that are looking into new, greener ways to power ships as they attempt to reduce sulphur and carbon emissions.

Green ship designs may include one particularly innovative project launched in 2001 by SkySails. The project unveiled the world's first kite propulsion system designed specifically for commercial shipping as well as luxury yachts. This propulsion system was designed to reduce fuel consumption, operating costs, and emissions. "We can demonstrate that you can combine economy and ecology," Verena Frank of Beluga Shipping explains, "Economy, because you can reduce fuel consumption and fuel costs, and on the ecological side of things, we reduce emissions." The first system was installed in 2007 on the MS Beluga Skysails on behalf of DHL Global Forwarding (an ocean and air freight company owned by the Deutsche Post World Net Group) (Konrad, 2010).

In a project supported by the Port of Long Beach, Toyota, and Tokyo-based shipping company NYK line, a greener, more efficient ship has been launched. Propelled by solar panels, the *Auriga Leader* is the first ship to use solar energy to power its main electrical grid. There are 328 panels that

Figure 1. The Maersk's Triple E is the world's largest container vessel. It represents a milestone in improvements in fuel efficiency and environmental friendliness. The ship achieves its efficiencies through innovative design features such as a smaller twin-engine and twin screw design. While the Triple E cruises the oceans at slightly slower speed than its counterparts, it does so with a nearly twenty percent increase in fuel economy. *(Photo Credit: Maersk)*

power the ship's thrusters and its hydraulics as well as steering and 10 percent of the ship's electricity (Parsons, 2009).

Another example is Maersk, a company that has just purchased 10 "Triple-E" vessels such as shown in Figure 1, with the intent to purchase twenty more in the near future. The vessels are considered to be the greenest container ships ever built, as well as the largest. This particular green ship offers energy efficiency, lowers the impact on the environment, and addresses economies of scale. Able to carry up to 16 percent more than current container ships, this ship will reduce the number of ships required to transport goods while also being energy efficient. (Dailey, 2011)

However, like other forms of transportation, it is not only the way we power them, it is also the danger associated with what we are transporting. On March 24, 1989 at 12:04 a.m., the most significant environmental disaster in human history occurred, made by the hands of mankind. The *Exxon Valdez*, an oil tanker, hit a reef in Alaska's Prince William Sound, emptying its massive belly of approximately 11 million gallons of oil. The ecosystems in its path were completely annihilated. Many marine animals, birds, and other living organisms in its path were injured or killed. Some marine life was saved by teams of workers removing the heavy oil and cleaning them, Figure 2. The spill covered a 10,000 square mile area, "an area the size of Connecticut, Delaware, Rhode Island, and 25 Washington, DC's combined" (Alaska Department of Environmental Conservation, 1993). There were many people involved in the cleanup of the Prince William Sound and surrounding areas.

Figure 2. Dr. Brian Stacy, NOAA veterinarian, cleans a young Kemp's Ridley turtle after the *Deep Water Horizon* Gulf of Mexico oil rig spill in 2010. A number of marine animals were spared by painstakingly cleaning them and later returning to their native waters.
(Photo Credit: NOAA/GADNR)

Today, the area has still not recovered from this catastrophic event. So, not only do we need to operate at an environmentally conscious level, we also need to think and have respect for where and how we operate. By implementing measures to reduce the risks of such accidents, we can reduce by 70-80% the risk of such a disaster happening again. We certainly cannot change what happened to the *Valdez*, but we can change what happens now and in our future. We have come to a point where our thinking has to change—the environment has become a priority.

Trucking

According to reports in 2008, the trucking industry is responsible for 22% of emissions from "transportation-related sources" and 6% of the total U.S. emissions (U.S. Department of Transportation, 2010). According to the report for the Pew Center on Global Climate Change mentioned at the beginning of this article, trucking accounts for 72 percent of "transportation energy and use and carbon emissions" (Greene & Schaefer, 2003).

Many companies are changing the way they operate their vehicles by instituting alternative fuel options as well as changing the way they do business. One example is United Parcel Service (UPS), which has looked at its operations and processes to come up with new ways to address efficiency as well as environmental issues.

UPS announced on March 23, 2010 that it would be launching a new initiative aimed at reducing its carbon footprint: an "eco-friendly shipping system" using innovative technology to ensure the least amount of waste possible. This new initiative looks at how deliveries and pickups are scheduled. For instance, a driver may stop at a customer's location to pick up packages only if they have packages ready to be shipped. In the past, businesses have been on a scheduled route where drivers stop regardless of whether or not the business has something to be shipped (Siranosian, 2010). UPS expects that this new initiative will save the equivalent of approximately 1,500 cars on the road annually, and: (a) eliminate 8 million miles from the total driven by UPS annually, (b) save approximately 793,000 gallons of fuel, and (c) reduce CO_2 emissions by 7,800 metric tons.

In addition, other companies are beginning to see the advantages of greener shipping, and many are converting fleets

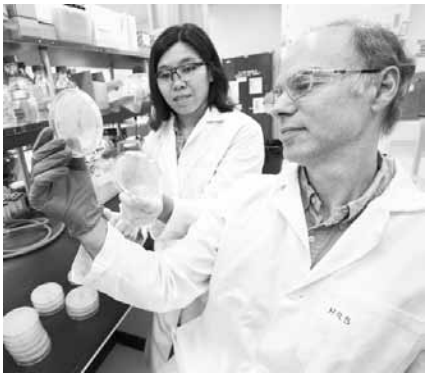

Photo by Roy Kaltschmidt, Berkeley Lab Public Affairs.

Figure 3. Harry Beller (foreground) and Ee-Been Goh of the Joint BioEnergy Institute have identified a trio of bacterial enzymes that can help convert plant sugars into hydrocarbon compounds for the production of green transportation fuels.

to natural-gas-powered or other alternatively fueled heavy trucks and vans such as Ryder and DHL (Cassidy, 2011). The transportation industry and consumers alike are concerned about the environment, energy resources, efficiencies, and economics. Improving transport fuel efficiencies is but one area where improvements and benefits to the environment can be realized. Scientists and researchers are continuing to make new discoveries and breakthroughs in alternative energy sources (Figure 3).

Air Transport

Although the shipping industry is going through vast changes, and trucks are looking at new ways to meet EPA regulations, the airlines have also agreed to cut emissions 50% by 2050. Air cargo accounts for 0.6 to 1.1 percent of all CO_2 emissions (Koch, 2011). Jet fuel costs have skyrocketed since 2005, from approximately $1.16 per gallon to over $3.30 per gallon in 2011 (American Airlines Cargo, 2011). This rise in fuel costs has spurred initiatives that address how companies can operate at more efficient levels as well as operations that promote efficiency and address issues related to the environment and pollutants.

One such example is American Airlines. Through the *Fuel Smart* program (initiated by employees) launched in 2005, American has made improvements to significantly reduce fuel consumption as well as its carbon footprint. By implementing *Fuel Smart*, American has realized a savings of more than 500 million gallons of fuel since its inception. Furthermore, American has reduced carbon dioxide (CO_2) emissions by more than 2.6 billion pounds annually. Prioritizing these ideas with the greatest savings and benefit to the environment has been important (American Airlines Cargo, 2011).

It has been estimated that American may have potentially saved as much as 134 million gallons of fuel in 2011, equating to a savings of approximately $442 million dollars. Lufthansa is another airline that is taking things very seriously and involving the public in its efforts. Recently, Lufthansa issued a challenge to anyone in the world to provide ideas for solutions to the airline in becoming greener. Using social media to "crowdsource" ideas, this initiative could generate the next creative solutions for a more efficient, greener Lufthansa Air Cargo. Three winners will be awarded a trip to Frankfurt, Germany to present their ideas to engineers and management. In addition, winners receive flight training with a captain of Lufthansa Air Cargo, and as many as 25,000 "Miles and More Miles" (Pal, 2011). Lufthansa is only one of many companies reaching out to the public and going the distance to generate a greener existence in business.

Pipeline

Pipelines transport fuels such as oil, natural gas, and biofuels. They are considered to be an integral part of the U.S. petroleum system, which meets petroleum demand. Without them, millions would be without the necessary fuels to heat their homes, drive their cars, or operate their businesses. Delivering over 600 billion gallons of fuel annually, they have become part of our environment, and as long as people depend on fuel, pipelines will be a necessity to the economy's supply and demand of this valuable commodity. Pipelines impact our environment much less than any other form of transportation, but they do have an initial and ongoing impact on the environment around them. Animals and other forms of life may be at risk with initial laying of pipelines, but it has been shown to be very little due to protective measures taken to preserve the environment during the planning and building phases. Air and water quality around the pipeline must be monitored to ensure that the environmental impact is minimal. In addition, other measures and precautions must be in place to manage pipelines, ensuring that they remain safe and secure. We hear very little about this type of transportation because it is the one method that least impacts our environment. The Alaskan Pipeline is a good model for sustainable development; the environment around it suffers very little from its presence.

Railway/Train System

According to the EPA in 2008 and also published in Norfolk Southern's 2010 Sustainability report, the trucking industry is responsible for 22% of emissions from "transportation-related sources" and 6% of the total U.S. emissions. The

railroads share amounts to 2.4% from "transportation-related sources" and 0.6% of the total U.S. emissions (Norfolk Southern, 2010).

Norfolk Southern Corporation, located in Norfolk, VA, is a major carrier of coal as well as industrial products. It operates in 22 states, covers approximately 20,000 miles, and services every major container port on the east coast of the U.S. (Norfolk Southern, 2011). The Associated Press (2012) recently reported that Norfolk Southern has loaded and shipped its "largest volume cargo in the 50-year history of its pier facility at Lamberts Point" by loading 160,000 net tons of metallurgical coal with a destination of China. The coal originated in mines located in southwest Virginia, the southern portion of West Virginia, eastern portions of Kentucky, and Pennsylvania (Associated Press, 2012) and can be used in the manufacture of steel and automobiles.

Railway operators realize that the environment is of key concern. "We recognize that our continued ability to thrive as a business is connected to the health of our communities, our environment, our employees, and our economy," notes CEO Wick Moorman (Norfolk Southern, 2011). According to Norfolk Southern's fourth annual sustainability report, in 2010 the company reduced greenhouse gases by 3.9% "per revenue-ton-mile of freight." Norfolk Southern hopes this percentage will increase to at least 10% by 2014 (Norfolk Southern, 2011).

In the railroad industry, pollution comes from not only operating locomotives and transporting goods; it comes from the crossties, rail, and ballast that are used to sustain a railway system. However, Norfolk Southern has taken steps to ensure materials are recycled and are not landing in landfills (batteries, crossties, scrap steel, etc.) (Norfolk Southern, 2010).

In addition to the diesel fuel that powers locomotives and operating supplies that can pollute the environment, trains also carry toxic and dangerous materials, passing hundreds of backyards, playgrounds, and parks. Traveling at speeds over 50mph, the potential for catastrophic damage to life and the environment when something goes wrong is ever present. Train cars can spill toxic chemicals, fuels, and other dangerous goods that can affect nearby homes, buildings, cars, and virtually anything in their path. Although train accidents are not a common occurrence, there have been accidents that have caused damage to the environment.

The EPA is issuing new standards to cut emissions from locomotive and marine diesel engines by approximately 90%. However, these new standards may not be effective until 2015. A three-part initiative developed by the EPA includes diesel locomotives (line-haul, switch, and passenger rail) and marine diesel engines (Environmental Protection Agency, 2011).

Besides the EPA, many initiatives are underway to encourage companies to initiate greener and more sustainable practices. In 2010, the Obama administration released new regulations focused on big trucks and heavy-duty vehicles, to begin with models to be manufactured in 2014. This initiative would cut greenhouse gas emissions and other pollutants by these vehicles as much as 20%. In addition, new models would be required to meet requirements of eight miles per gallon as compared to the current six miles per gallon on most models. Lisa Jackson, EPA Administrator, says that "these new standards are another step in our work to develop a new generation of clean, fuel-efficient American vehicles that will improve our environment and strengthen our economy" (Banerjee, 2010).

Federal research grants and other support is available for projects that sustain the development and implementation of greener shipping and port management, air travel, truck shipping, and railroad transportation. In addition, private companies are taking initiatives as well. If every business on the globe announced one initiative to make changes to their business processes and operations, a greener, more sustainable environment is inevitable.

Design Initiative for Students

As students enter the class they will see an image of a local highway after a busy morning. The street and the surrounding area are covered with a variety of land-based debris. They will see a shocking photograph with a caption reading: "Your ignorance did this—Learn, and save the environment."

After a few minutes, ask the students if they know who is responsible for the mess at the highway and if there is something they can do to save the habitat and keep the highways clean. Assign groups of three, where students will be responsible to investigate, conduct research, and come up with solutions that lead to a healthier environment. Once solutions have been identified, they should be presented to the rest of the class. Students subsequently begin a plan of work to solve the problem. The teacher may provide ideas such as a day trip to the city or the local beach to clean the area, or arrange a meeting with the local police officer to discuss the issue. Ask students to research, identify, and prepare a list

of responsible environmental interest groups. The students should select several organizations and describe the kinds of projects and activities that the groups support and how they benefit society and the environment. Additionally, students may write to several of the organizations describing their support and concerns. Activities such as the one described above are easy to correlate with the technological literacy content standards created by the International Technology Education Association (ITEA/ITEEA) in 2000. See Table 2 for correlations with ITEEA's standards.

Summary

A *quote* found in a Greenpeace advertisement states: "It wasn't the *Exxon Valdez* captain's driving that caused the Alaskan oil spill. It was yours" (ADEC, 1993). It is vital that we promote the protection of the environment and strengthen the laws that prohibit waste dumping so the surroundings stay clean and healthy; otherwise, the direct output of this concept—the existence of humanity in the years to come—will be questionable.

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Table 2.
Correlation with *Standards for Technological Literacy*

The Nature of Technology	Technology and Society	Design
Standard 1: Students will develop an understanding of the characteristics and scope of technology.	**Standard 4:** Students will develop an understanding of the cultural, social, economic, and political effects of technology.	**Standard 8:** Students will develop an understanding of the attributes of design.
Standard 2: Students will develop an understanding of the core concepts of technology.	**Standard 5:** Students will develop an understanding of the effects of technology on the environment.	**Standard 9:** Students will develop an understanding of engineering design.
Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.	**Standard 6:** Students will develop an understanding of the role of society in the development and use of technology.	**Standard 10:** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
	Standard 7: Students will develop an understanding of the influence of technology on history.	

Adapted from *Standards for Technological Literacy: Content for the Study of Technology* (ITEA/ITEEA). (2000/2002/2007).

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Petros J. Katsioloudis, PhD *is an Ambassador to Cyprus for the International Technology Education and Engineering Association. He is an Assistant Professor in the Department of STEM Education and Professional Studies at Old Dominion University in Norfolk, VA. He can be reached via email at pkatsiol@odu.edu.*

Mildred V. Jones *is a senior in the Department of STEM Education and Professional Studies at Old Dominion University. She can be reached at mjones@odu.edu.*