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Energy and Emissions in Transportation: How Mikhail Chester Makes it Easier to be Green

As we've all learned in recent years, travel, by car, bus, train, or plane, has varying consequences that can be calculated in terms of the amount of energy consumed and emissions spewed into the atmosphere.

But direct energy use and harmful emissions are only part of the problem. Indirect and supply chain costs are harder to enumerate and measure, yet significant. To truly understand real costs in terms of energy use and polluting byproducts, it is necessary to analyze the lifecycle of a particular vehicle or group of vehicles and their infrastructures from cradle to grave. That means calculating the energy used and environmental impacts of building a roadway, say, or constructing an underground BART station, or maintaining the floors of Caltrain cars, or junking a jet.

As policy makers struggle to write environmental regulations and develop transportation plans for the future, it is critical to acknowledge and calculate these lifecycle costs rather than making decisions based simply on tailpipe emissions. And if the task of sorting out and quantifying all these pieces of various transportation modes that use energy and contribute to harmful emissions seems daunting, well, as a famous frog once warbled, "It ain't easy being green."

Former Civil and Environmental Engineering grad student, Mikhail Chester, and his adviser, CEE Associate Professor Arpad Horvath, however, have taken a big step toward making it easier. Four years ago, when Chester started on the road toward a PhD, he set out to produce the first comprehensive environmental lifecycle assessment of passenger transportation modes in the U.S.

The zero emission AC transit bus may eliminate pollutants from its tailpipe, but that's only part of the problem. The manufacturing of its parts, maintenance, the required infrastructure—asphalt roadways—also require energy and produce harmful emissions. (Photo by M. Chester)

Horvath's primary research area is lifecycle assessment. Under his guidance another former CEE grad student, Cristiano Facanha, had tackled the lifecycle of freight in the U.S. a few years earlier. Taking on passenger travel was an even more complex challenge because of the multitude of transportation options, and for Chester, one that would become his doctoral thesis.

Recently, Chester, who has conducted research as part of ITS' Center for Future Urban Transport, and Horvath published their preliminary results in a paper titled "Environmental Life-cycle Assessment of Passenger Transportation: A Detailed Methodology for Energy, Greenhouse Gas, and Criteria Pollutant Inventories of Automobiles, Buses, Light Rail, Heavy Rail and Air."

Comparing and Contrasting Modes

PDF of article

Chester, now a post-doc, has gathered or, in cases where it didn't exist, developed data for five modes of passenger travel—automobile, bus, heavy rail, light rail, and air. Based on those modes and the 12 sample vehicles (ranging from a Toyota Camry to a Boeing 747) used in his investigation, he provides an environmental inventory of more than 100 different components that affect energy use, contribute to greenhouse gases, and produce other direct human health impacting pollutants across the five modes. These include not only the manufacturing, maintenance, and operation of the specific vehicles, but also the building and maintenance of the infrastructure they require and the fuel they consume, from the oil field to the gas station. The inventory runs the gamut from a bus's idling to an aircraft's take-off and landing, from laying down rail tracks to roadway maintenance and pesticide use.

As greener jet fuels are developed, aircraft emissions will be reduced. But runways, taxiways, tarmac, airport parking lots, runway lighting, ground support equipment, and a host of other components necessary to air travel require energy and degrade the environment. (Photo by M. Chester)

Then he normalized the numbers to determine the environmental performance of each vehicle per vehicle and passenger mile traveled. When factoring in the lifecycle of each mode, he found that energy and greenhouse gas emissions increase by 1.3 times for automobiles, 1.4 times for buses, 2.6 times for light rail, 2.1 times for heavy rail, and 1.3 times for air. Criteria pollutant and volatile organic compound emissions (sulfur dioxide, carbon monoxide, nitrogen oxides, particulate matter, and lead) rise a whopping 25 times for automobiles, seven times for buses, 220 times for light rail, 98 times for heavy rail, and 11 times for air.

Chester acknowledges that his study is not the first lifecycle assessment of passenger transportation, but he believes it is the most thorough to date.

"We have not seen this comprehensive a lifecycle assessment that includes the number of components we included…an inventory that quantifies the total environmental performance of each mode with such a comprehensive list of components," he told NewsBITS. Horvath added, "This has been a lot of work, but there is really no other way to determine the environmental footprint of transportation. One has to fill in all the gaps. Everything else is a surrogate and incomplete measure."

For each mode Chester has quantified 30 to 40 components; some shared—like the use of asphalt and concrete in construction of roadways, railroad stations, and runways—some unique to a mode—like production and application of de-icing chemicals for aircraft operation.

"Infrastructure components for a car are much different than infrastructure components for a plane, but we have inventoried infrastructure components and maintenance for both of them," he explained.

After several years of digging for data, determining which data were reliable, and constructing data where it did not exist, he came up with results: some intriguing, others surprising. For example:

Roadway construction particulate matter emissions are as large as tail-pipe emissions for the automobile per passenger-mile-traveled.

• Urban buses with peak-hour occupancies have the best energy and greenhouse gas performance, followed by rail and then air systems, and trailed by automobiles. But off-peak bus travel is the worst performer.

• Air travel is environmentally competitive with rail travel and can outperform rail modes when the aircraft is about 80 percent utilized.

• The use of ground support equipment at airports contributes roughly one-third of the total carbon monoxide lifecycle emissions for aircraft.

• While rail systems are the best energy and greenhouse gas performers, they exhibit the largest shares from infrastructure effects in the lifecycle. This results from environmentally much larger infrastructure requirements per passenger-mile served.

High-Speed Rail in California

One of the more interesting, and relevant in this election year, calculations are performed by Chester for the yet-to-be-funded California High-Speed Rail project. Since it does not yet exist, he used information based on European high-speed trains as well as proposed system designs. He determined that California's proposed high-speed rail will perform well—better than the automobile and aircraft--but only if it gets the high ridership proponents suggest it will. And the history of transit projects, he says, shows they rarely manage to attract the high ridership they predict.

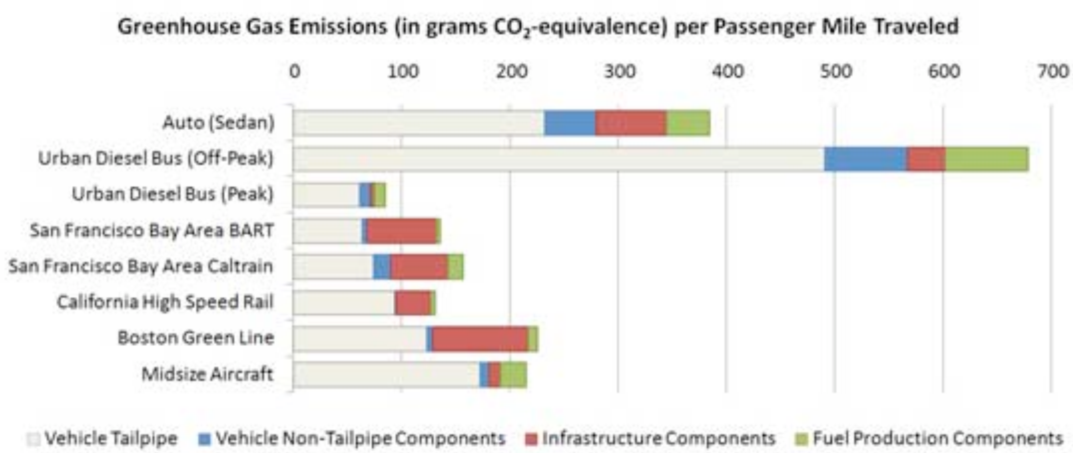
If high-speed rail draws only half the ridership it says it will attract, its environmental performance will be twice as bad per passenger miles traveled. And, if compared to typical aircraft travel in situations where 70 percent of rail passenger seats are filled, high-speed rail performs worse (the crossover occurs when high-speed rail achieves 65 percent of estimated ridership compared against current aircraft utilization rates at 70 percent).

When Chester began this project, he hoped it would result in something that "wouldn't just sit on a shelf." He believes he has succeeded. Although his extensive inventory doesn't cover every automobile, bus, plane, or train model, it provides a template and methodology that allows others to plug in data for a specific vehicle or operating condition and produce a reliable lifecycle assessment. As he points out, many of the components for automobiles—asphalt, roadway lighting, manufacturing—will remain the same except for minor differences specific to a particular model.

He points out that knowing just how large the role of asphalt production plays, for example, in energy consumption and emissions for automobiles and buses can guide researchers to provide new and better methods for manufacturing and using it in the infrastructures of various transportation modes.

He takes heart, too, in the response he has received since the paper was posted on the ITS Web site through the publications database.

"We've had calls from federal transportation officials and one of the largest global airlines," he said, adding that the document has been downloaded more than 100 times in the last 10 months. A magazine has asked him to use his methodology to determine the effects of motorcycle travel. So the work for Chester and Professor Horvath will continue.



Average occupancies are shown with the exception of the Urban Bus which has 5 passengers during off-peak times and 40 during peak times.
"Vehicle Tailpipe" represents emissions from gasoline, diesel, or electricity use in active operation. "Vehicle Non-Tailpipe Components" are components associated with the vehicle outside of active operation (e.g. manufacturing, maintenance, etcetera).
"Infrastructure Components" capture construction, maintenance, operation, and other materials, processes, and services required to build and operate each mode's infrastructure.
"Fuel Production Components" capture the emissions from gasoline, diesel, electricity, and other fuel input production including mining, refining, production, and distribution.

Important Links:

"Environmental Life-cycle Assessment of Passenger Transportation" Project Web site.

Mikhail Chester's Home page

PDF of the abstract of Mikhail Chester's ITS Friday seminar of August 29, 2008, "An Environmental Life-Cycle Inventory of Passenger Transportation in the United States."

Professor Arpad Horvath's Home page:

Freight LCA papers by Cristiano Facanha and Arpad Horvath:
Environmental Assessment of Freight Transportation in the U.S. (11 pp)
Evaluation of Life-Cycle Air Emission Factors of Freight Transportation

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PDF of article

