Lifecycle Environmental Impact of High-Speed Rail System in the I-45 Corridor

Evaluating environmental impacts of the Houston-Dallas high speed rail system and performing a comparative assessment with road and air transport

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Texas has the highest rate of energy-related greenhouse gas (GHG) emissions, and transportation is one of the major contributors. The Houston–Dallas corridor is one of the busiest routes in Texas. Recently, the development of an intercity High Speed Rail System (HSR) with Shinkansen N700 series trains has commenced. This study builds the lifecycle inventories for vehicles and infrastructure in the HSR system, and conducts a preliminary environmental lifecycle assessment. Results indicate that over the design life of the HSR system the total GHG emissions from the vehicle life-time are 9.695 kgCO2eq/VKT, and fossil-fuel usage during vehicle operation is the primary contributor (97%). For the infrastructure, total life-time GHG emissions are 239 kgCO2eq/VKT, out of which, 94% are from the construction stage. Infrastructure is the dominant contributor to end-point impacts in human health category, with 58% of total impact across all damage categories.

Background

Life Cycle Assessment (LCA) studies for high-speed rail (HSR) projects in the US are constrained by methodological uncertainties and knowledge gaps in estimating the changes in environmental, human health, resource, and climate impacts. Key challenges encountered during LCA studies is a lack of data and methods for estimating degree of passenger migration to the HSR mode. A lifecycle GHG emissions from infrastructure construction for California's HSR system between San Francisco and Anaheim estimated the route will result in 2.4 million metric tons of CO_2, of which material production stage contributes around 80% and transportation of materials contributes around 16%. Previous research also compared the environmental effects of HSR systems to road/air travel under varying degrees of ridership forecast, from a low-level ridership estimate of 10% passenger occupancy to a high-level of 100% occupancy, and normalized the energy/environmental intensities per passenger kilometer traveled (PKT).

The HSR project in Texas is being designed to function with Japanese N700-I Tokaido Shinkansen passenger rail system and would require the estimates for vehicle production and electricity consumption accordingly. Lifecycle inventory data for the latest N700 Series trains is limited; however, simulations conducted by Railway Technical Research Institute (RTRI), Japan CO_2 emissions of Series 700 trains operating between Tokyo and Shin-Osaka is estimated as 6,310 tons/vehicle for a train with 16-cars.

Project Summary

The overall goal of this study is to provide an estimate of the environmental impacts resulting from the total life cycle of the Houston-Dallas HSR system. Following are the major objectives to realize the overall goal:

- Develop the framework for methodological environmental LCA of current/proposed HSR corridors in south-central US;
- Estimate the net change in GHG emissions and global warming potential ($CO_{2,}$ eq) due to the Houston-Dallas HSR system;
- Evaluate the effect of the HSR system in improving regional air quality of Texas;
- Compare improvements in sustainability resulting from the HSR system under varying degrees of traffic migration/passenger adoption;
- Analyze the effect of source electricity mix scenarios on the environmental impacts from the operation phase of the proposed HSR system; and
- Provide guidance to stakeholders, policy makers and community leaders on the potential environmental benefits/costs of HSR mode of transportation in U.S.

Status Update

The main task accomplished were centered on the evaluation of total system life cycle impact using the selected functional unit of Vehicle Kilometers Traveled (VKT). Figure 1 shows the end-point life cycle impacts for infrastructure and the vehicle. The impact from individual stages were also evaluated and the normalized energy consumption during construction, and GHG emissions are detailed in Figure 2. Although Fossil fuel is the dominant source during construction, the majority of energy for infrastructure comes from hard coal, and for the vehicle, natural gas has the highest contribution.

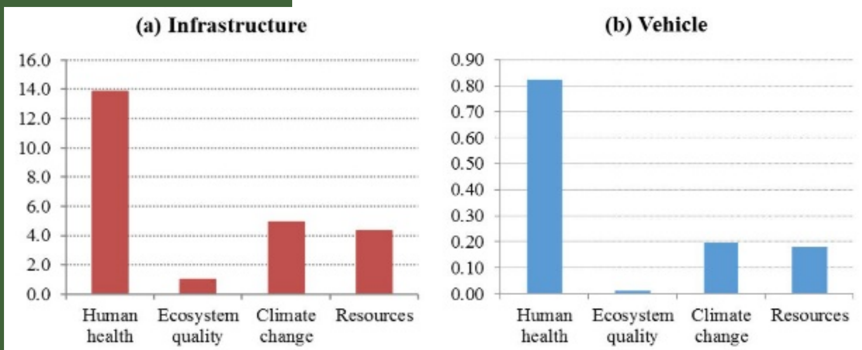

Figure 1. End-point impacts of Life Cycle HSR system analysis.

This research evaluated the trends of criteria air pollutants (CAP) in and compared data with similar studies in Europe. Nevertheless, they all have direct contribution to the increase in GHG emissions. In addition, it was also observed that despite the reduction on most CAPs, for carbon monoxide there is an increase of about 1.75 ratio. The increase in carbon monoxide emissions reflects the transportation emissions from the heavy tracks and other heavy equipment used for transportation of material and personal during the four years construction period.

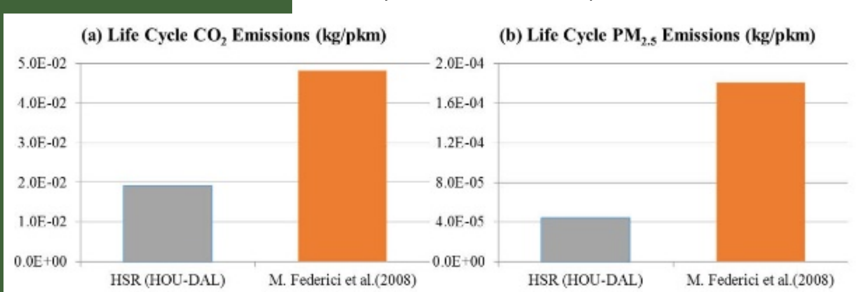

Figure 2. Comparison of I-45 HSR emissions with Italian Raliway System.

This study uses SimaPro 8.5® and the Ecoinvent 3.3 inventory database, and estimated the net change in environmental impacts across 14-midpoint and 4-endpoint impact categories using Impact 2002+ life cycle impact assessment method. The system boundary for the LCA study covers two major components: (1) lifecycle of infrastructure, which includes stages, raw material extraction, manufacturing, operation & maintenance, and end-of-life, as well as transportation and (2) complete lifecycle of the N700 trains manufactured in Japan and transported to U.S. Results indicate that over the 20-year design life of the HSR system the total GHG emissions from the vehicle life-time would be 9.695 kgCO2eq/VKT, out of which the fossil-fuel usage during vehicle operation is the primary contributor, accounting for 97% of the GHG emissions. For the infrastructure, total life-time GHG emissions would be 239 kgCO2eq/VKT, out of which, 94% are from the construction stage. Infrastructure is the dominant contributor to end-point impacts in human health category, with 58% of total impact across all damage categories. Within human health category, PM2.5 is the major factor, and originate from fossil-fueled electricity generation and processing stage of construction materials. Preliminary comparison with other HSR systems in Italy indicate that the I-45 system would have 40% lower life cycle CO2 emissions.

Impacts

This project would provide quantitative estimates for the total life cycle environmental impact from the high-speed rail system in Houston-Dallas I-45 corridor. This includes estimates of the CO2 payback times and the necessary passenger adoption levels to offset air and water pollutant emissions during the construction. A comparative assessment with existing transportation models such as road, and air would be very valuable in environmental planning and lowering the overall contribution of transportation to greenhouse gases levels.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

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