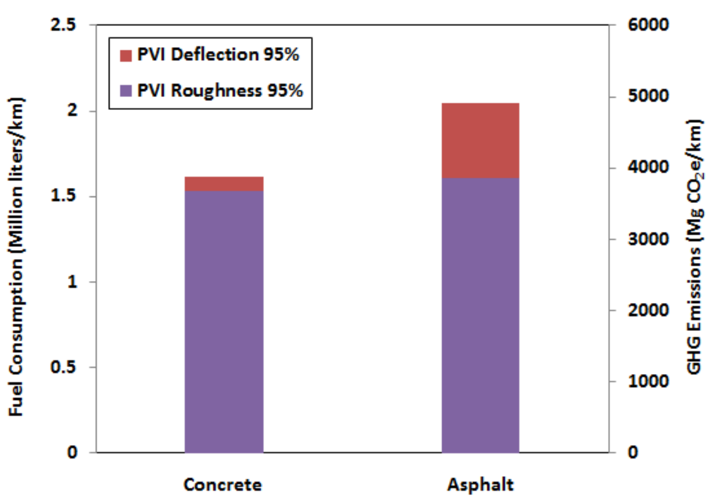
Network, Pavements, and Fuel Consumption

Problem

Sustainability of the roadway transportation sector is highly dependent on passenger and commercial vehicle fuel consumption. The roadway system affects this fuel consumption via pavement-vehicle interaction (PVI) in two major ways: pavement deflection and roughness. Both sources of PVI are dependent on material and structural properties of the pavement. In addition, ineffectual application of maintenance and rehabilitation strategies throughout the pavement lifetime can significantly affect a pavement's environmental performance and durability. In order for the impacts of PVI to be captured within pavement design procedures and life cycle assessment models, the combined effect of the PVI elements (deflection and roughness) along with that of maintenance and rehabilitation scenarios must be understood and quantified. The impacts of PVI on fuel consumption are not constant and evolve over time, mainly due to pavement deterioration from loading and environmental factors. Calculation of the excess fuel consumption due to pavement conditions throughout their lifetime draws a perspective on the environmental benefits of reducing PVI, through better design, material, and maintenance schedules.



Sample Output: Excess fuel consumption and resulting CO_2e emissions for two high-volume pavement systems for a 50 year design life using a 95% confidence interval. (Two-lane kilometer section design from Athena (2006); AADT=15,000; AADTT 1,500; AC maintenance at years: 17, 28, 38, 47; PCC maintenance at years 20, 40).

Approach

In order to calculate the impact of pavement deflection and roughness along with that of maintenance on the vehicle fuel consumption, an analysis on the current state of the roadway Network has been performed using the long term pavement performance program (LTPP) databases as a representation of the network. According to the theory of ergodicity, a dynamic system such as a road network has the same behavior averaged over time as averaged over space. Hence, we use structural and material properties of the LTPP sections as inputs for the PVI deflection model, and the roughness values through the international roughness index (IRI) for the roughness model. By applying these models to a high-volume pavement scenario we can calculate the extra fuel consumption due to these impacts throughout the lifetime of a pavement.

Findings

For the high-volume roadway analyzed, we find that the contribution of both pavement deflection and roughness to added fuel consumption are significant. Since a Network analysis is performed, the results represent the state of the pavement throughout its lifetime. Considering a 95% confidence interval of the available network data, the impact of pavement deflection is more pronounced on asphalt pavements, while the impact of roughness on PVI is almost identical for asphalt and concrete.

Impact

Quantifying the impacts of pavement properties and management strategies on vehicle fuel consumption can provide guidance to pavement design and maintenance schedules while reducing the footprint of these systems. Although the impact of pavement roughness is higher than that of deflection, both are highly important within the environmental analyses of pavement systems, and greatly influence the aggregated vehicle fuel consumption.

More

A comprehensive research report on model-based PVI simulation for LCA of pavement by M. Akbarian and F.-J. Ulm is available at http://web.mit.edu/cshub/.

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