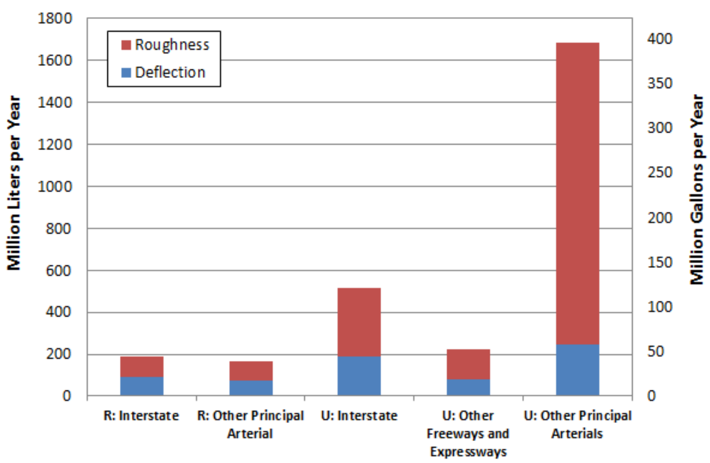
Concrete Sustainability Hub@MIT – Life Cycle Assessment Research Brief – 7/2012

Potential Roadway Network Savings and PVI

Problem

It is now generally agreed that Pavement-Vehicle Interactions (PVI) contribute significantly to the 174 billion gallons of fuel used annually in the ground transportation sector which is responsible for about 20% of the total US CO_2 emissions. A 1% reduction in vehicle fuel consumption through better pavement design and management can lead to Greenhouse Gas emission savings of as much as 15.5 million tons of CO_2 per year. Specifically, pavement stiffness and roughness are the main contributors to PVI, and relate to the pavement structural and surface conditions. In return, these conditions heavily depend on pavement age and management strategies (maintenance, etc.). Our previous research focused on quantifying the aggregated impact of roughness and deflection on fuel consumption at the scale of the 8.5 million lane miles of the paved public US roadway network. In turn, this research aims at quantifying the current "mileage" of our road system for different functional systems, as set forth by FHWA's Highway Statistics classifications: rural and urban interstate roads, other principal arterials, freeways and expressways. Such a refined analysis is expected to provide a better understanding of the significance of proper pavement design and management, and a first step toward identifying the most efficient improvement strategies for different systems and decision makers at the federal, state and local city level.



Excess fuel consumption per year on rural (R) and urban (U) highways, due to pavement deflection and roughness at 95% confidence interval. Pavement properties, roughness, and traffic volume have been extracted from the LTPP database and the FHWA Highway Statistics manual.

Approach

The impact of PVI on fuel consumption for each functional system is calculated by combining the MIT PVI-deflection model with a semi-empirical roughness model. Model inputs are provided from the LTPP databases and the 2008 FHWA Highway Statistics manual. Distributions for pavement structural and material properties are extracted from the LTPP database. Distributions of roughness values along with traffic volume of each functional system were drawn from the FHWA Highway Statistics manual. Using Monte-Carlo simulations for each functional system, the excess fuel consumption ("mileage") due to PVI of these pavements compared to that of a flat pavement with roughness of 63 in/mile is calculated.

Findings

Analyses of the five functional systems show that an aggregated 740 million gallons of extra fuel are consumed per year to overcome resisting forces due to deflection and roughness. It is found that the impact of roughness and deflection are on the same order of magnitude; except for Urban Other Principal Arterials where apparent higher roughness magnifies the roughness impact. In contrast, Interstates are found to be better maintained due to their heavy usage, translating in a higher mileage and smaller ecological footprint. As such, in addition to improved pavement management, agencies can reduce their excess fuel consumption further by building pavements that stay smoother longer; and increase the pavement stiffness by using improved material properties or increased layer thickness for sustainable concrete, asphalt or composite pavements.

Impact

Analyses of the impact of PVI on vehicle fuel consumption for different roadway functional systems demonstrate the impact of pavement design and management on vehicle fuel consumption. Such analyses can provide direction for future investments in maintenance, rehabilitation, and reconstruction of the pavement network to reduce its impact on PVI.

More

Research presented by Mehdi Akbarian, graduate student in the CSHub, supervised by Prof. Franz-Josef Ulm.

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