

An Overview of CSHub Pavements Research

According to the Environmental Protection Agency, U.S. road transportation accounts for 83% of greenhouse gas (GHG) emissions from the transportation sector and 27% of all GHG emissions in the U.S. The road system, which requires 350 million tons of materials annually for maintenance, earned a D grade from the American Society of Civil Engineers (ASCE) on their 2017 report card, which was no change from the last report card released in 2013. The 2017 report also noted that more than two out of every five miles of America's urban interstates are congested, with traffic delays costing the country some \$160 billion in wasted time and fuel.

For the foreseeable future, U.S. infrastructure funding will remain significantly below what is required to improve conditions and performance. Because of the environmental impact of pavements and the economic challenge of building and maintaining them, there is a growing need to better quantify performance and cost over pavements' entire life cycle.

To meet that need, the MIT Concrete Sustainability Hub (CSHub) is developing tools and data for decision-makers to evaluate pavement designs and make choices that are both cost-effective and environmentally responsible. CSHub research results are peer-reviewed.

The Lifecycle of Pavements

CSHub researchers are examining the cost and environmental impacts for the full life of pavements and are creating integrated life-cycle assessment (LCA)



and life-cycle cost analysis (LCCA) tools that account for the use and maintenance phase of pavements—not just the costs or GHG emissions that occur during initial construction.

Since past research into pavement LCCA and LCA has looked at specific case studies, it has proven difficult to apply this research across a wide array of contexts, including maintenance, schedule, traffic level, and climate. CSHub researchers have therefore investigated numerous paving scenarios across various contexts to provide stakeholders with a more widely applicable way to understand the factors that impact the environmental and financial outcomes of their paving decisions.

Planning future maintenance schedules also entails confronting considerable uncertainty and variation. However, many departments of transportation (DOTs) still take a deterministic approach that considers only

one set of unchanging future conditions. While simpler to conduct, a deterministic approach is less accurate, especially if these future conditions change unpredictably. CSHub probabilistic LCCA models provide agencies with a more streamlined way to manage these uncertainties and lower their long-term expenditures.

To learn more about pavement LCA, visit <https://cshub.mit.edu/pavements>.

To learn more about pavement LCCA, visit <https://cshub.mit.edu/pavements/lcca>.

Pavement Vehicle Interaction (PVI)

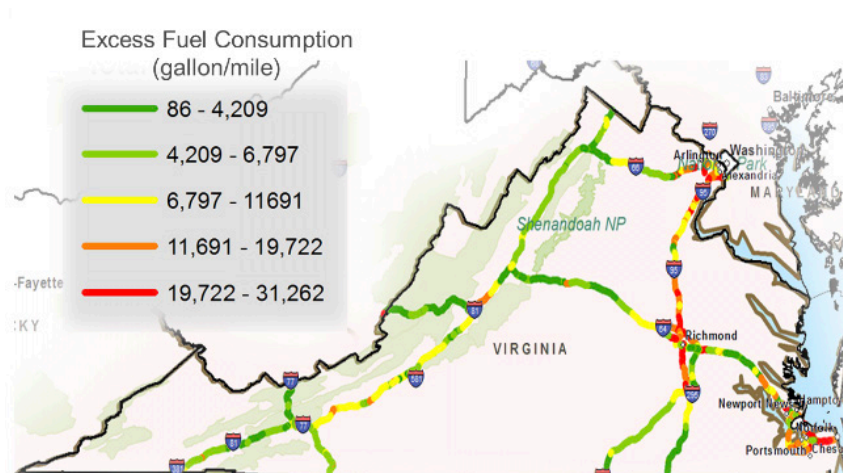
When discussing the life cycle analysis of pavement networks, it is vital to consider not just the construction and maintenance of pavements, but also their operational life. In fact, a significant portion of a pavement's environmental impact derives from its use—specifically from a phenomenon called pavement-vehicle interaction (PVI).

PVI refers to the interaction between a road's surface and a vehicle's tires. It can increase the fuel consumption of vehicles, contributing to smog and greenhouse gas emissions.

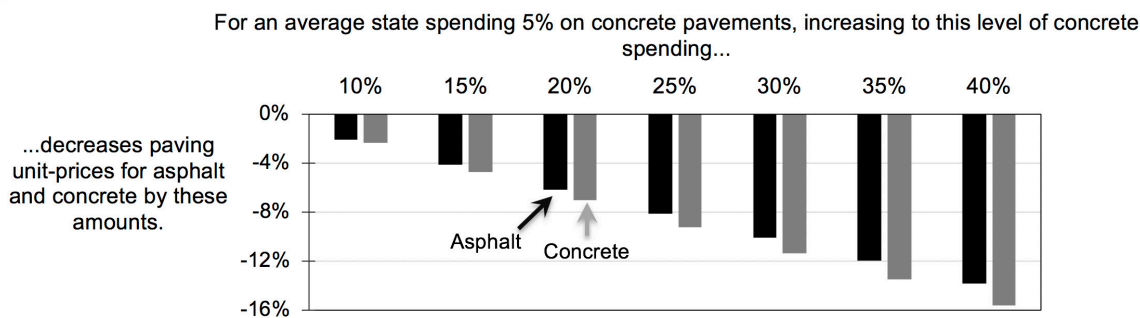
CSHub researchers aim to quantify and reduce PVI induced-emissions. In an analysis of the pavement network managed by the California Department of Transportation (~50,000 lane-miles), they identified 1 billion gallons of excess fuel consumption (EFC) due to PVI over a 5-year period. Another study of Virginia's highway network found 1 million tons of CO₂ from EFC over a 7-year period (see figure below). By maintaining smoother and stiffer pavements, DOTs can minimize these PVI impacts.

Just as with a pavement's life cycle cost, its PVI emissions can also vary by context. CSHub research investigates how contextual factors like traffic, climate, and pavement design can influence PVI, and therefore, the lifetime environmental impact of a pavement.

To learn more, visit <https://cshub.mit.edu/pavements/pvi>



Understanding PVI is essential to the analysis of the lifetime environmental impacts of pavements. On Virginia's highway networks, for instance, CSHub researchers found that 1.3% of the network is responsible for 10% of its total greenhouse gas emissions. Rehabilitating just a few of those lane miles could result in significant environmental improvements.



For states to minimize expenditures on paving material, a competition must exist between paving industries.

Industry Competition

When sustained competition exists in a market, the price for similar goods is expected to go down. Researchers examine how this fundamental economic principle affects the price of paving materials. Their findings suggest that intra-industry competition among paving material manufacturers lowers the unit price of both concrete and asphalt.

These savings are possible because of the current lack of competition in the paving industry: all U.S. states surveyed by MIT spent at least 68% of their paving budget on asphalt pavements for DOT projects and, in some states, virtually no competition existed between paving industries.

After analyzing the various drivers of paving material bid prices, researchers found that interindustry competition had the greatest influence on both concrete and asphalt prices. For states that spent 5% on concrete, an increase to 40% spending on concrete would lead to an approximately 16% decrease in both asphalt and concrete prices (see figure above).

To learn more, visit <https://cshub.mit.edu/pavements/competition>

Asset Management

According to the American Society of Civil Engineers, chronic underfunding for the highway system has led to \$836 billion-dollar backlog of repairs. To manage their pavement networks with low funds, DOTs employ tools like performance-based planning (PBP), which use past data to project future pavement performance, spending, and environmental targets. However, these projections are often fraught with uncertainties in cost and deterioration. CSHub researchers have developed new approaches that give DOTs the ability to better manage these uncertainties.

In a case study of North Carolina, researchers found that by employing a CSHub designed PBP, the same levels of performance and emissions were possible at a significantly lower cost. Specifically, their work found that a mix of pavement types and long and short-term fixes along with a longer planning horizon could save tens of millions of dollars over a pavement's lifetime.

To learn more, visit <https://cshub.mit.edu/pavements/asset-management>

Albedo

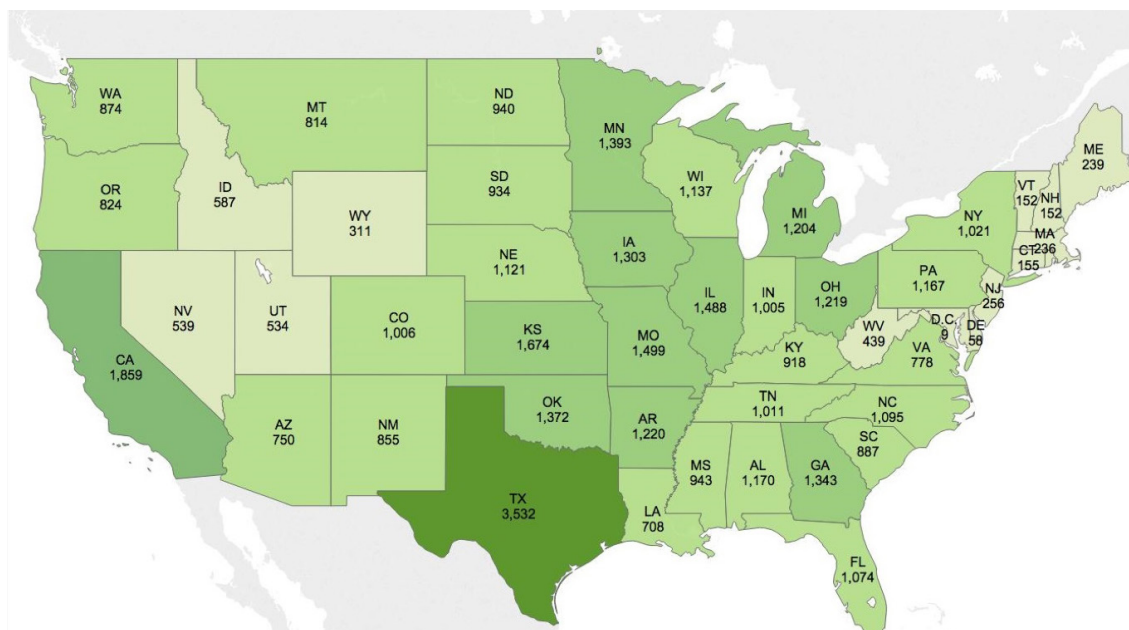
Rapid urbanization across the world has dramatically changed land use and surface properties of cities. In the U.S., for instance, 30-45% of urban surfaces are now composed of pavements. Depending on their albedo, or surface reflectivity, urban pavements can absorb or reflect enough solar radiation to alter a city's climate.

CSHub research investigates how the albedo of pavements can be harnessed to mitigate climate change (see figure below). By being modified to reflect more light, pavements can lower air temperatures, reduce HVAC loads, and minimize human health risks. CSHub researchers have found that a moderate increase in pavement albedo would lower heat waves by 41% in U.S. cities and lead to greenhouse gas savings equivalent to removing 9.4 million passenger vehicles from U.S. roads.

To learn more, visit <https://cshub.mit.edu/pavements/albedo>

References

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Annual greenhouse gas emission savings in thousands of tonnes due to a moderate albedo increase in all urban and rural roads across the U.S.

This research was carried out by CSHub with sponsorship provided by the Portland Cement Association and the Ready Mixed Concrete Research & Education Foundation. CSHub is solely responsible for content.