How to Improve Pavement Life Cycle Cost Analysis: A Case Study of Minnesota[1]

Research Brief, Volume 4, 2017

PROBLEM

Given the aging roadway infrastructure in the US, shortage in paving funds, and new MAP-21 regulations on pavement management requirements, planning agencies are looking for effective and risk aware ways to manage the life-cycle economic impact of their transportation investments. Life cycle cost analysis (LCCA) frameworks are used by some transportation agencies for economic assessment, but there have been challenges implementing the approach, particularly characterization of initial and future costs of materials, as well as their associated uncertainties. This study focuses on characterizing initial and future pay item costs as a function of project size for a probabilistic LCCA of the entire life cycle including user cost impacts.

APPROACH

Researchers integrated previous work on probabilistic LCCA models[2], initial cost characterization of construction pay-items[3], future price projection of paving materials[4], and excess fuel consumption models due to roughness- and deflection-induced PVI[5,6]. These models were applied to pavement sections selected by MnDOT to study price characterization, integration of uncertainty, and calculation of user cost in a LCCA. The probabilistic LCCA model accounts for variations in all elements of the life cycle. Pay item unit-prices are related to quantity to address economies of scale, where materials cost less for larger projects. A long-run material price forecast was developed for asphalt and concrete materials based on MnDOT's paving cost index.

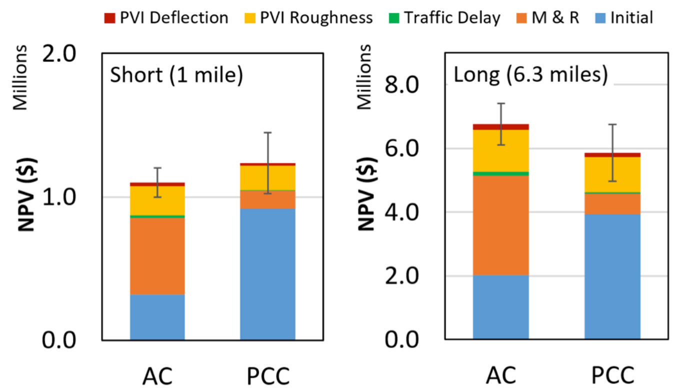

Figure 1 – Impact of project size on total life cycle cost of pavements including agency costs from initial and maintenance and rehabilitation (M&R), and user costs from PVI and traffic delay. The AC and PCC designs are independent of section length. The error bars represent the standard deviation of probabilistic initial, M&R, and deflection-induced PVI results. Traffic delay costs and roughness-induced PVI are deterministic.

FINDINGS

A selection of case study results[1] is presented in Figure 1. Researchers observed that asphalt (AC) sections benefit from low initial cost compared to the concrete (PCC) alternatives, however, the asphalt sections accrue more maintenance and rehabilitation (M&R) costs through the 35-year analysis period. Furthermore, comparison of the lowest cost scenario between Figure 1 (short) and (long) shows the significant impact of economy of scale on the final choice. While the AC design is the lowest cost scenario for short sections, PCC section benefits from a lower price at a larger scale and is the lowest cost scenario for the long sections. Also, future price forecasts showed a 50% reduction in estimation error of AC and PCC prices over a two-decade period, compared to the current assumption that prices grow with the inflation rate. Lastly, it is shown that PVI is a dominant contributor to user costs during the life cycle and is comparable to M&R agency costs.

WHY DOES THIS RESEARCH MATTER?

- The proposed LCCA framework addresses current gaps in analysis through a probabilistic approach, initial and future price characterization, and inclusion of user costs.
- Identified economy-of-scale as low-hanging fruit for improving agency LCCAs given its significant contribution to prices and project selection (MnDOT implementing).
- Developed price forecasts that increase confidence at both national and state level.
- Demonstrated advantages of probabilistic LCCA in evaluating risk due to uncertainty.

This research was carried out by the CSHub@MIT with sponsorship provided by the Portland Cement Association and the Ready Mixed Concrete Research & Education Foundation. CSHub@MIT is solely responsible for content.
Authors: Mehdi Akbarian, Omar Swei, Jeremy Gregory, Randy Kirchain.

How to Improve Pavement Life Cycle Cost Analysis: A Case Study of Minnesota[1]

Research Brief, Volume 4, 2017

---

1. Full paper: Probabilistic Characterization of Life-Cycle Agency and User Costs: Case Study in Minnesota. Journal of TRR-TRB. 2017.

2. Swei, et al. Probabilistic Life-Cycle Cost Analysis of Pavements: Drivers of Variation and Implications of Context.

3. Swei, et al. Probabilistic Characterization of Uncertain Inputs in the Life-Cycle Cost Analysis of Pavements.

4. Swei, et al. A Probabilistic Approach for Long-run Price Projections: Case Study of Concrete and Asphalt.

5. Akbarian, M. Quantitative sustainability assessment of PVI: from bench-top experiments to integrated road network analysis.

6. Louhghalam, et al. Scaling relations of dissipation-induced pavement-vehicle interactions.

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

Authors: Mehdi Akbarian, Omar Swei, Jeremy Gregory, Randy Kirchain.