Material Price Projections for Pavement Life Cycle Cost Analysis

Motivation

Practitioners increasingly use life cycle cost analysis (LCCA) in the pavement selection process. One uncertain input parameter that has an impact on decisions in paving projects is the impact of future cost changes for rehabilitation and reconstruction events. However, existing pavement LCCA frameworks overlook price change as a consideration largely because, to date, little research has evaluated the performance of forecasting pavement material costs over extended time-horizons.

Research by the Concrete Sustainability Hub (CSHub) at MIT has validated the effectiveness of probabilistic real-price projections at the national level. The fidelity of such models had not been tested at the state level. Results from a collaboration project with the state of Colorado Department of Transportation (DOT) suggests that such forecasting approaches could also be used at the state level in order to allow decision-makers to make more informed choices.

Approach

LCCA Cost Estimating Practices

Life cycle cost analysis (LCCA) is an analytical technique that can be used to compare alternative designs by considering significant costs over a defined analysis period. For an LCCA to be meaningful, credible, and provide the information needed to make the best selection, the economic analysis must reflect the most likely expenditures for each alternative over the analysis period as accurately as possible.

The current LCCA practice is to assume that the price of all inputs grow with the general rate of inflation. This means that future costs are predicted to inflate at the same rate as the average for all goods and services in the economy (quantified as the consumer price index - CPI). However, national data from the Bureau of Labor Statistics (BLS) shows that construction material prices have evolved differently from general inflation, as shown in Figure 1.

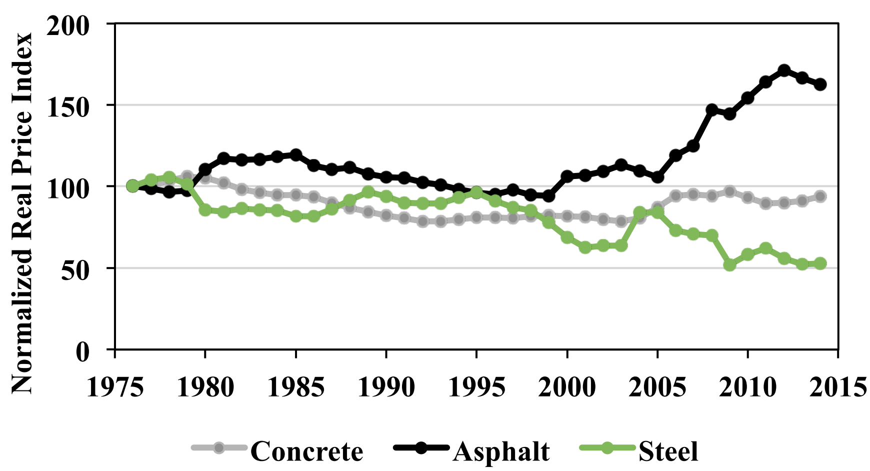

Figure 1: Historical real prices of concrete, asphalt, and steel since 1976, per BLS. A price of 100 matches the consumer price index.

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Publication/Revision Date: March 2016

The data demonstrate that the practice of assuming that prices grow at a steady rate tied to average economic inflation in an LCCA (also known as no change in real price) is inconsistent with how the historical price of these commodities have actually evolved over time. MIT has developed forecasting models for material-specific projections that can be incorporated in LCCAs.

CSHub Projection Model Background

Researchers in the construction community typically forecast prices of commodities by employing traditional models that rely on one variable. Unfortunately, the performance of such models is largely driven by data availability that, for asphalt and concrete, is fairly limited. However, because significant empirical data that precedes the early 1900s does exist for many of the key constituents for paving materials, such as cement, oil, and aggregate, it is possible to take a hybrid approach where prices of constituent materials are projected using traditional time-series techniques and a long-run price trend between paving materials and constituents is established making use of those forecasts. Previous research by the CSHub has demonstrated that the models described here not only outperform current practice on average in the long run, but also easily support current probabilistic, risk-based LCCA paradigms.

MIT CSHub, Colorado DOT Project Background

The Concrete Sustainability Hub (CSHub) at MIT conducted a research project with the Colorado Department of Transportation (CDOT) to look at how the state could improve their existing life cycle cost analysis (LCCA) practices. Since Colorado is one of the few states already using probabilistic LCCA (a method which accounts for variability and uncertainty), the joint project allowed CSHub researchers to validate their model. One of the issues the project set out to investigate was whether alternative methods of projecting paving material prices in the state of Colorado would be an improvement over the existing assumption that future prices grow with inflation (e.g., *constant* real prices). The project also included an analysis of three Colorado paving projects representing a range of scales (low, medium, and high volume). MIT conducted LCCAs for the projects using projected real price changes, a probabilistic LCCA model, and an approach for incorporating outputs from the mechanistic empirical pavement design guide (MEPDG) into a probabilistic LCCA.

Material-specific price projection models for Colorado were based upon national-level forecasts previously developed by the CSHub but scaled to the state level. Since national data sets provide more extensive information than state data sets, which may only include a few decades of prices, CSHub researchers selected this approach. Researchers looked at how well price projections starting from 1987 would have predicted rehabilitation costs using CDOT's standard current practice (no change in real prices) and MIT's forecasting models. Then used the data to determine if accounting for these changes produced better results than the current no change assumption and were able to show that using material-specific projections improves the accuracy of LCCAs.

Findings

Results of the analysis suggested that concrete and asphalt price forecasts, which are based on advanced time-series techniques, outperformed conventional assumptions and existing methods. When applied to Colorado, the forecasting model, on average, led to more accurate forecasts than current practice, as shown in Figure 2; for example, the average error of the CSHub models 20 years into the future was 46 percent and 32 percent less than current practice for asphalt and concrete.

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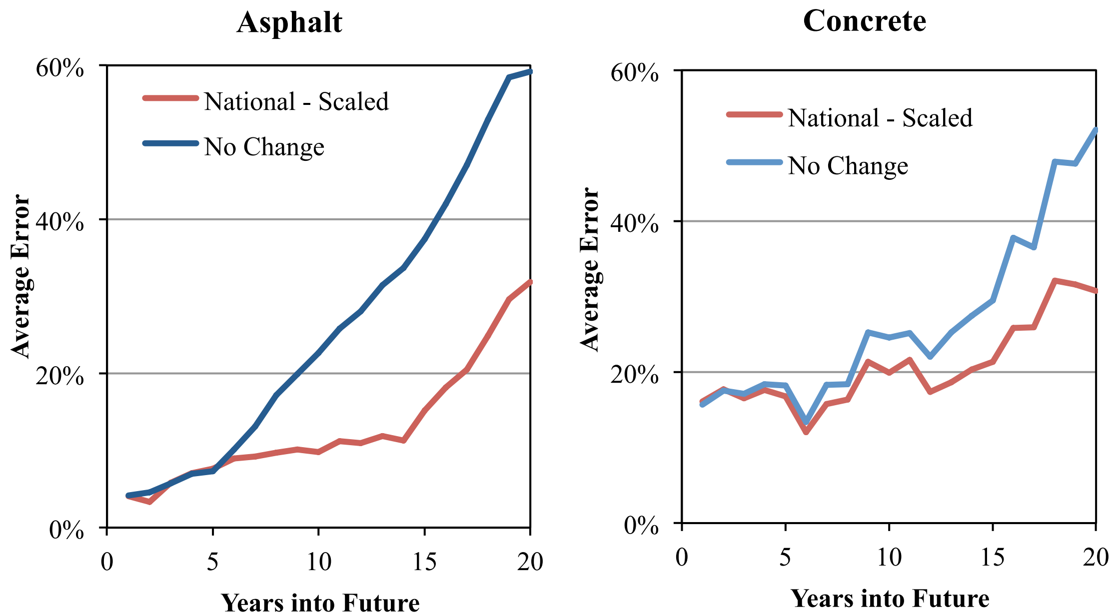

Figure 2: The average error of price forecasts made between 1976-1990 for Colorado using current-practice (labeled "No Change") and CSHub method (labeled "National – Scaled"). The left plot is for asphalt, and the right plot is for concrete.

Other Findings from the Research Partnership

- Initial cost uncertainty proved to be a particularly important driver of variation in life cycle cost and requires further analysis.
  - The research showed that initial cost variation tends to exhibit economies of scale and that variation in cost for larger projects is much lower than for smaller projects.
  - MIT's process makes it possible to better understand the cost implications of a design created using standard pavement engineering software because material quantities and pavement deterioration information is transferred to the LCCA.
- Integration of standard pavement engineering software, such as AASHTO's Pavement-ME, and LCCA means that the predicted pavement distress can be used to estimate things like maintenance schedules and material quantities.
  - One finding showed that expected life-cycle costs can differ significantly using a traditional CDOT maintenance schedule compared to one predicted by the pavement software.

Impact

For LCCAs to provide the best information possible and lead to better decisions, the cost estimates must reflect, as accurately as possible, the most likely expenditures for each alternative over the analysis period. The research the CSHub conducted with CDOT shows that material specific price projections are more accurate than the conventional assumption that pavement prices follow the average rate of economic inflation. Not taking into account different inflation rates among construction materials can have significant impacts on LCCA estimates and, hence, the allocation of DOT resources.

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Relevant Peer Reviewed Publications

O.A. Swei, J.R. Gregory, R.E. Kirchain, "Developing Paving Material Price Projection Models for Incorporation in Life Cycle Cost Analysis", *accepted for publication in Journal of Construction Engineering and Management,* 2016.

O.A. Swei, J.R. Gregory, and R.E. Kirchain, "Probabilistic Life-Cycle Cost Analysis of Pavements: Drivers of Variation and Implications of Context", *Transportation Research Record: Journal of the Transportation Research Board*, 2523: 47-55, 2015, http://dx.doi.org/10.3141/2523-06.

O.A. Swei, J.R. Gregory, and R.E. Kirchain, "Probabilistic Characterization of Uncertain Inputs in the Life-Cycle Cost Analysis of Pavements", *Transportation Research Record: Journal of the Transportation Research Board*, 2366: 71-77, 2013, http://dx.doi.org/10.3141/2366-09.

O. Swei, S. Greene, J. Gregory, R. Kirchain, "Back to the future: using historic data to improve pavement material price projections", Concrete Sustainability Hub report, http://cshub.mit.edu/sites/default/files/documents/MaterialsCostProjection_v11.pdf, August 2013.

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