The influence of incorporating uncertainties and treatment path dependence in performance-based planning analyses

Research Brief, Issue 8, Volume 2018

PROBLEM

According to the American Society of Civil Engineers' (ASCE) 2017 Infrastructure Report Card, the backlog for repair of existing highways across the U.S. totals approximately $420 million. With funding at all-time lows, it is important for agencies to have efficient budget allocation models for the selection of maintenance, rehabilitation & reconstruction (MRR) activities. One key consideration during the allocation process is the evaluation of each available treatment. Most existing allocation models use a benefit-cost ratio to evaluate treatments. This approach, while convenient, is limited because it only considers the benefits of a current treatment and assumes a known, fixed future. The models also tend to consider only a limited number of treatments. For example, when evaluating an asphalt overlay, existing approaches tend to assume that the next treatment will be another asphalt overlay, which might not always yield the best results. The CSHub has developed a new approach called the probabilistic treatment path dependence (PTPD) model in which MRR treatment decisions consider the benefits of each possible action, along with the likelihood of future conditions (e.g., road deterioration, prices, etc), and suggest the optimal future actions to regardless of future uncertainty. To return to the previous example, with this approach, when evaluating an asphalt overlay, we assume that it may be followed by an asphalt overlay or a concrete overlay, depending on best case scenarios in regards to future prices and the rate of deterioration. This research brief focuses on the benefits of incorporating uncertainties and treatment path dependence by comparison between the conventional benefit cost ratio (B/C) model and the new PTPD model.

APPROACH

The PTPD model includes two steps to allocate budget. The first one involves a segment-level analysis that identifies the best MRR alternatives for all segments across the pavement network. However, no state has enough budget to implement the best MRR treatments for all segments every year. Hence, the second step is to select the segments to receive MRR treatment in a year given the limited budget. Unlike exiting budget allocation models, the PTPD model considers different futures. To evaluate those futures, the PTPD model considers that DOTs may make different choices depending on future prices and deterioration by incorporating treatment path dependence and uncertainty.

FINDINGS

We demonstrate the benefits of this new model by comparing it with a conventional B/C model. The comparison is based on a pavement network consisting of 30 segments and the analysis period is 20 years. Figure 1 shows the annual traffic weighted IRI (TWIRI) distribution of the pavement network for B/C and PTPD. The solid line is the average TWIRI and the shaded area represents the distribution. For the first 5 years, the B/C model performs better since it has a smaller TWIRI. However, after a small increase of TWIRI for the first several years, PTPD is shown to have a faster decreasing rate and a smaller average TWIRI after ten years. To achieve a similar performance level, the B/C model needs a budget increase of 15%. By examining the treatment actions chosen by the models, we found that the PTPD model chooses more reconstruction actions, especially for the first 10 years, which explains the initial increase in TWIRI. However, after several years, long-term benefits of reconstruction emerge and the PTPD model suggests a shift to minor and major rehabilitations for the last ten years.

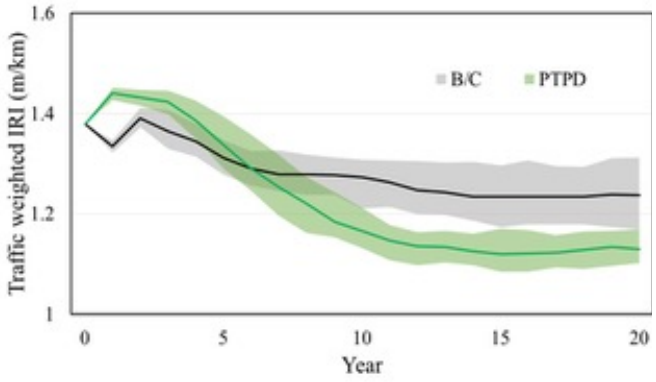

Figure 1: Annual traffic weighted IRI distribution of the pavement network for B/C and PTPD.

WHY DOES THIS RESEARCH MATTER?

- A preservation strategy that only focuses on maintenance cannot improve network performance in the long term. A holistic approach to evaluating MRR strategies together is necessary.
- Using a range of pavement technologies is the only way to improve network performance in a cost-effective way.
- Incorporating uncertainty and treatment path dependence enables the true long-term value of expensive reconstructions and rehabilitations to be considered.

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: Fengdi Guo, Jeremy Gregory, Randolph Kirchain