SJSU SAN JOSÉ STATE UNIVERSITY

MTI MINETA TRANSPORTATION INSTITUTE

Development of a Statistical Model to Predict Materials' Unit Prices for Future Maintenance and Rehabilitation in Highway Life Cycle Cost Analysis

Project 1806
December 2020

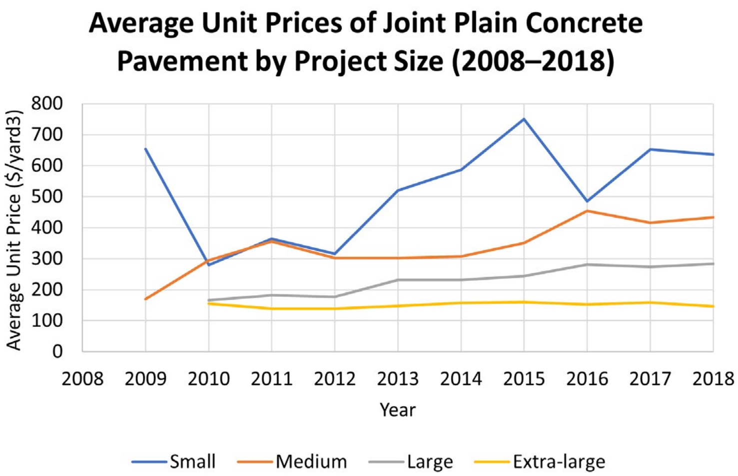
Changmo Kim, PhD, Ghazan Khan, PhD, Brent Nguyen, and Emily L. Hoang

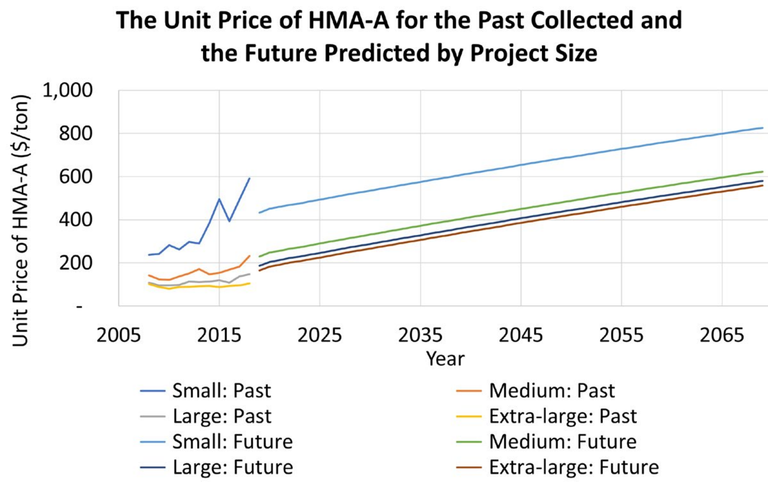
Life cycle cost analysis (LCCA) technique has been used in California since 2007 to compare the cost-effectiveness of design alternatives such as pavement materials and cross-sections for Caltrans highway projects. The cost calculation module of the existing Caltrans LCCA software, RealCost 2.5CA, requires a unit price per material to calculate the cost of future maintenance and rehabilitation (M&R) projects. Caltrans LCCA procedure manual guides users to use the statewide uniform unit prices as the default or find the relevant unit prices from the Caltrans historical contract cost database. However, materials' unit prices vary over time given the project size or due to additional factors. The unit price entered by a user to calculate the future M&R project cost for a long-term LCCA period, typically 50–60 years without considering unit price variability, may result in inaccurate results.

The previous studies in the literature show that current methods of LCCA still result in biased estimates; however, applying principles of maximum likelihood can reduce the biases naturally present in material and construction costs.

Many state transportation agencies maintain construction cost data through webpages with unit price information for the past years. This information is useful for contractors who prepare project bid documents and for pavement designers who compare design alternatives. This research collected and investigated the socio-economic parameters related to highway construction and identified the correlations among them. Four representative socio-economic parameters were selected: national crude oil price, California population, number of vehicles registered in California, and State budget expenditure in transportation; their future values were predicted for the next 50 years of LCCA using a time-series model, autoregressive integrated moving average (ARIMA). The ARIMA model smoothed the unique decline phenomenon of the three socio-economic parameters, except for population, during the U.S. economic recession (approximately 2008–2012), and predicted their future values for LCCA period (2020–2069). The selected parameters were set to be the independent variables of the multiple regression models to estimate the pavement materials' unit price for the future M&R activities of each alternative in the LCCA period.

The primary pavement material items' unit prices in the past 20 years (1999–2018), collected from the Caltrans Construction Contract Cost database, were analyzed by project size. The unit prices of each pavement material were categorized by the material quantity into four categories (small, medium, large, and extra-large projects), and the annual average unit prices were calculated in each category. The project size was used as the independent binomial variable, and the unit prices was the dependent variable in the multiple regression models. The multiple regression models estimated the annual unit prices of each pavement material for the next 50 years (2020–2069). The R-squared values are in the range between 0.5 and 0.9. Due to the lack of projects used some unpopular material items, the average unit prices were not available in some project categories during the data collection period. The authors recommend using the latest unit prices of the materials having less than five years of unit price information, instead of using the predicted unit prices in the model that might be biased until the price information become available at least next five years. On the other hand, the models predicted the future annual unit prices by project size for the material items used in a large number of projects in the past years, such as Roadway





Excavation, Class 2 aggregate base, type A hot mix asphalt (HMA-A), rubberized hot mix asphalt (RHMA), jointed plain concrete pavement (JPCP), and lean concrete base (LCB). These models were verified using the unit prices in the recent projects in the case study.

A case study compared the LCCA results using the model-predicted unit prices for the future M&R with the results from the uniform unit prices used in the current procedure. The net present values (NPVs) of the life cycle agency costs calculated by the model-predicted unit prices were higher than those calculated by the uniform unit prices for both alternatives: HMA-A with 20-year design life and JPCP with 40-year design life. In the case study, JPCP with 40-year design life was still more cost-effective than HMA-A with 20-year design life for the life cycle analysis period when used the model-predicted unit prices.

In LCCA, long-term prediction must account for uncertainties due to the unexpectable economy and industry demand-supply conditions. Economic recessions and a global pandemic are examples that pose critical influences in changing future material unit prices and project costs. Nevertheless, the data-driven scientific approach reduces risks caused by these uncertainties and enables reasonable predictions for the future. The models developed in this research can be implemented to enhance the current LCCA procedure to predict more realistic unit prices and project costs for the future M&R activities and thus select the most cost-effective alternative in LCCA.

About the Authors

Dr. Changmo Kim is a project manager at the University of California Pavement Research Center at Berkeley and Davis. Dr. Kim, as a part-time faculty, teaches Transportation Engineering courses in the Department of Civil Engineering at Sacramento State. Dr. Ghazan Khan is an Associate Professor in the Department of Civil Engineering at Sacramento State. His teaching and research focuses on Transportation Engineering, Traffic Operations and Safety, Geographic Information Systems (GIS), and Statistics.

To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/1806

MINETA TRANSPORTATION INSTITUTE

MTI is a University Transportation Center sponsored by the U.S. Department of Transportation's Office of the Assistant Secretary for Research and Technology and by Caltrans. The Institute is located within San José State University's Lucas Graduate School of Business.