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September 2012

RESEARCH PROJECT TITLE
Asset Management and Safety: A Performance Perspective

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Midwest Transportation Consortium (MTC Project 2009-01)

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The mission of the Center for Transportation Research and Education (CTRE) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, and reliability while improving the learning environment of students, faculty, and staff in transportation-related fields.

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Asset Management and Safety: A Performance Perspective

tech transfer summary

Incorporating safety performance measures into asset management can assist transportation agencies in managing their aging assets efficiently and improve system-wide safety.

Problem Statement

Past research has revealed the relationship between individual asset performance and safety, but the relationship between combined measures of operational asset condition and safety performance has not been explored.

Research Description and Methods

This project investigates the effect of pavement marking retroreflectivity and pavement condition on safety in a multi-objective manner. Data on one-mile segments for all Iowa primary roads from 2004 through 2009 were collected from the Iowa Department of Transportation (DOT) and integrated using linear referencing.

The researchers used route milepost-based integration to integrate the crash data and the condition data of the roadway segments and developed a methodology for estimating a composite asset condition index (ACI).

The ACI was estimated for the road segments by scoring and weighting individual pavement condition and pavement marking components.

Statistical models were then developed to estimate the relationship between ACI and expected number of crashes, while accounting for exposure (average daily traffic or ADT).

Finally, the researchers evaluated alternative treatment strategies for pavements and pavement markings using benefit-cost ratio analysis, taking into account corresponding treatment costs and safety benefits in terms of crash reduction (number of crashes proportionate to crash severity).

Key Findings

Estimation of Asset Condition Index

The ACI was developed as a simple, convenient, and easy-to-understand indicator for representing the overall physical asset condition of a roadway segment and assisting agencies in decision-making for pavement preservation and maintenance activities.

The researchers developed a step-by-step methodology for calculating the unique condition index using multiple asset condition measures. The methodology involved scoring and weighting asset condition components, such as pavement condition and pavement retroreflectivity, as well as their subcomponents.

The resulting ACI values range from 1 (indicating poor condition) to 3 (indicating good condition).

Statistical Analysis
Negative binomial models were estimated to predict the relationship between crash frequency and ACI, while accounting for exposure. The estimation results indicated that the higher the ACI of a roadway segment, the lower the expected number of crashes.

In addition, the researchers found that separate negative binomial models for different ACI ranges explain the relationship among crash frequency, ACI, and ADT better than a single model. The impact of ACI on crash frequency for roadway segments with an ACI lower or equal to 1.5 was greater compared to that for roadway segments with an ACI higher than 1.5.

Economic Analysis
Both short-term and long-term safety benefits in terms of crash reduction along with treatment costs were estimated for six alternative treatment strategies via a single-year benefit-cost ratio (BCR) analysis and a five-year net present value (NPV) analysis.

Minor rehabilitation and use of durable pavement marking materials are recommended as more cost-effective treatment alternatives in the short-term. In the long-term, the same recommendation holds for segments with an ACI higher than 2.0. For segments with an ACI lower than 1.5, major rehabilitation and tape marking are recommended.

Study Limitations

Data Integration
In the GIS-based integration procedure, the tolerance of spatial joining was set as 10 meters, which means that a crash location could be marked potentially as far as 10 meters away from the pavement and the roadway. This assumption affects the assignment of crashes to roadway segments and, potentially, the level of accuracy.

Data
The pavement marking retroreflectivity data were collected every five miles, while all other datasets were recorded per mile. As a result, only one of five segments was assigned a pavement marking condition and this caused a lot of missing data in the final dataset.

To resolve the missing data issues, the researchers assumed that the pavement marking condition of road segments within a five-mile segment would be the same. As such, the same values were recorded for segments 2.5 miles forward and backward of the available data point.

The crash data included all crashes that occurred on Iowa's primary roads from 2004 through 2009. It was assumed that all crashes were related either directly or indirectly to asset condition and were considered for further analysis. Hence, our results may overestimate the effect of asset condition on safety.

Estimation of ACI
The thresholds that were used for the operational performance subcomponents (such as IRI, faulting, paint, etc.) to classify segments into ACI categories from 1 through 3 were based on the literature. The researchers recommend that an expert panel review these thresholds and scores as well.

Statistical Analysis
In this study, all crashes were considered as related to asset condition. The contributing factors related to the characteristics of the driver, vehicle, and roadway environment (besides roadway condition) were not taken into account in the data collection and statistical analysis.

Economic Analysis
The discount rate throughout the economic analysis was assumed to be four percent. This rate is commonly used for benefit-cost analysis; however, during the analysis period, the banking discount/interest rate was lower (approximately one percent).

Secondly, the researchers applied straight-line depreciation to calculate asset condition depreciation. In fact, the depreciation rate could follow normal, exponential, logarithmic, and other distributions, depending on the asset characteristics.

Finally, the study period for the second approach was set as five years. Usually, when alternatives have different service lives, the study period of economic analysis should be the lowest common multiple of the service lives.

Future Study Recommendations
To understand the relationship between asset performance and safety performance better, the following recommendations are offered for future studies.

- *Analysis of future data:* A longer study period for the database developed in this study would help to define the relationship between asset performance and safety performance more accurately. A further process of relating crashes to asset performance measures, based on crash reasons, is expected to improve the accuracy of the research.
- *Replication of this study in other states:* A replication of this study in other states would help verify the results and/or identify differences among states. Similar data resources would be necessary.
- *Consideration of additional asset performance measures:* Only pavement condition and pavement marking performance were included in this study. Additional asset conditions that could be considered in future work include sign inventory, lighting inventory, rumble strip inventory, or guardrail locations.