Motivation

Commercial motor vehicles travel an average of 294 million miles daily on Indiana’s roads. State agencies have implemented weigh-in-motion (WIM) sensors to weigh, count, and classify commercial vehicles at highway speeds. Recent advancements in communications, computational capacity, and memory storage have enabled real-time recording and permanent storage of data from every WIM station statewide. Improperly loaded commercial vehicles cause exponentially greater damage to roadways. In the year 2016 alone, INDOT’s WIM stations produced approximately 550 million total vehicle records per year. This study had two objectives:

1. Develop “Big Data” data mining procedures and tools to screen WIM stations’ “health” to determine early indications on when a WIM may need maintenance.
2. Ground truth selected WIM sites using adjacent Indiana State Police static scales.

Data Analytics

This study develops database tools to analyze 3.5 years of INDOT WIM data to compare systematic procedures for identifying WIM stations with measurement errors. The front axle and left-right residual weight quality control methods developed in past literature are implemented in automated software, and five case studies are presented for analysis. Since regularly performing on-site calibration is typically a costly undertaking, the goal of this study is to use software and data mining techniques to identify sensor out-of-range locations to enable a data-driven protocol for WIM site maintenance.

Some performance metrics were identified for assessing the quality of WIM stations, including daily median class 9 front axle weight, daily median class 9 front axle left-right residual, and pavement smoothness near the WIM station. A newly constructed VWIM station sampled nearly 616,000 class 9 vehicles and revealed that 85% of all class 9 front axle weights fell between 10,000 and 12,000 pounds. This performance metric can be used to identify poorly functioning WIM stations remotely. Pavement smoothness can significantly affect the integrity of the weight data obtained by a WIM station. Historical data also revealed the effects of WIM calibration on the data.

Field Validation Results

Field validation was performed on two WIM stations by comparing the WIM weights to weights obtained at Indiana State Police—certified static weigh scales. The truck weight was observed and recorded at each location and results were later compared for analysis. A 5-month study on I-94 collected 564 static weights and found that 98% of the VWIM weights were within ±5% of the static weights. A second study on I-70 collected 262 static weights and found that 87% of the WIM weights were within ±5% of the static weights after statistical adjustment. A larger spread of percent error was seen on the I-70 WIM, while the I-94 VWIM had a smaller spread. However, it should be noted that in both cases the percent errors were generally spread evenly and centered on zero, which is indicative of normal random measurement error. Pavement grinding was performed on the I-94 site before VWIM installation for improved pavement smoothness. The I-70 site did not have any special pavement preparation.
Truck weight comparison example on I-70 WIM

Recommendations

Pavement smoothness is critical to a properly functioning WIM station; therefore pavement smoothness should be considered before construction completion is approved. Additionally, systematic smoothness evaluations should be conducted on a regular basis. Field validation of the two WIM sites shows a larger spread of percent error on the I-70 INDOT site that doesn’t meet smoothness specifications than on a brand new site that maintained tight construction and calibration tolerances. (However, even the I-94 site pavement smoothness did not meet recommended standards for WIMs according to ProVAL\(^1\) and AASHTO MP 14-05 (2012)\(^2\)).

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\(^1\)http://www.roadprofile.com/download/Implementation-of-OWL.pdf.