INDOT Research

TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

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Quality Control Procedures for Weigh-in-Motion Data

Introduction

For the past two decades, weigh-in-motion (WIM) sensors have been used in the United States to collect vehicle weight data for designing pavements and monitoring their performance. The use of these sensors is being expanded for enforcement purposes to screen vehicles in traffic streams for overweight violations. This screening procedure is broadly referred to as a virtual weigh station. WIM sensors are also used at static weigh stations for screening vehicles to be stopped and weighed statically, resulting in reduced driver delay and increased efficiency by only weighing trucks that are close to the legal weight limit. The effectiveness of static weigh stations in Indiana for identifying overweight trucks has not been previously documented. Therefore, it was not possible to determine if the virtual weigh stations were a more effective tool and warrant widespread deployment across the state.

The WIM enforcement applications require a high level of data accuracy for optimal performance. This level of accuracy has been difficult to achieve with the traditional planning and design applications because the data is aggregated and not scrutinized for individual vehicles. If the WIM sensor is weighing too light, illegal trucks may not be identified reducing the enforcement effectiveness. If the WIM sensor is weighing too heavy, legal trucks may be identified as overweight reducing the enforcement efficiency.

This project was initiated to develop a quality control program for the Indiana Department of Transportation (INDOT) to improve the accuracy of the data produced from the WIM system. The quality control program provides a mechanism for assessing the accuracy of vehicle classification, weight, speed, and axle spacing data and monitoring it over time.

Findings

This study found that static weigh stations in Indiana were effective for identifying safety violations, but ineffective for identifying overweight vehicles. It was also determined that the virtual weigh stations in Indiana were found to be approximately 55 times more effective than the static weigh stations for overweight truck identification. To achieve that level of effectiveness, the virtual weigh stations require a high level of WIM data accuracy and reliability that can only be attained with a rigorous quality control program. Accurate WIM data is also essential to the success of the Long-term Pavement Performance project and the development of new pavement design methods.

Robust metrics were identified for the quality control program that can be continuously monitored using statistical process control procedures that differentiate between sensor noise and events that require intervention. The speed and axle spacing accuracy is assessed by examining the drive tandem axle spacing of the Class 9 vehicle. The population average of this metric should range between 4.30 and 4.36 feet. The weight accuracy is assessed by examining the total steer axle weight and left-right steer axle residual of the Class 9 vehicle population. The population average steer axle weight should range between 9,000 and 11,000 lbs depending on the percentage of loaded vehicles. The population average left-right residual should range between -6% and +6% depending on the cross-slope of the roadway. The sensor error rates can be assessed and monitored by computing the proportion of errors relative to the number of vehicles.

An example of the accuracy and monitoring reports developed in this project for the speed accuracy, weight accuracy, and error rates are depicted in Figure 1, Figure 2, and Figure 3, respectively. The system accuracy charts (Figure 1a, Figure 2a, Figure 3a) include the average values for each WIM lane in the entire system. If a lane's value is outside of the target range, a statistical process control chart (Figure 1b, Figure 2b, Figure 3b) for that lane is used to determine if the deviation is attributed to random variation or a sensor problem.

Data mining of the accuracy metrics revealed variations in the data caused by sensor failure and sensor drift, sometimes attributed to temperature and precipitation, and incorrect calibration. The statistical process control charts revealed that the WIM sensor measurements are not in statistical control and frequently drift out of calibration. To establish and maintain accurate data, the WIM data should be continuously monitored for errors and drifts. It is also recommended that the system algorithms consider variations in the climate to account for temperature and precipitation or flag data that is collected during days of climatic anomalies when the accuracy is questionable.

Implementation

This report developed a set of tools that the Indiana Department of Transportation can use to assess WIM data accuracy and monitor that accuracy over time. Implementing the following items will establish and make use of these tools to improve the overall accuracy of the WIM systems in Indiana:

- Implement procedures for importing WIM data into a relational database. This will facilitate the creation of the analysis cube files that are essential for data manipulation and exploration.
- Apply the drive tandem axle spacing metric to all WIM systems to monitor the speed calibration and prioritize maintenance on a lane basis.
- For lanes with poor speed calibration, approximate the calibration using the average drive tandem axle spacing metric prior to field calibration using a laser gun.
- Apply the error proportion metric to all WIM systems to identify lanes that experience high error rates to prioritize maintenance on a lane basis.
- Configure bending plate and single load cell WIM systems to log the left and right wheel data to compute the left-right residual metric. Use the left-right residual for detecting weight calibration drift and to prioritize maintenance on a lane basis.
- Construct a test bed of various types of WIM sensors for a long-term evaluation of performance, accuracy, and maintenance costs for each type. Installation of necessary equipment to collect continuous climate data adjacent to the test bed would allow further exploration of the climatic impacts on the WIM sensors.

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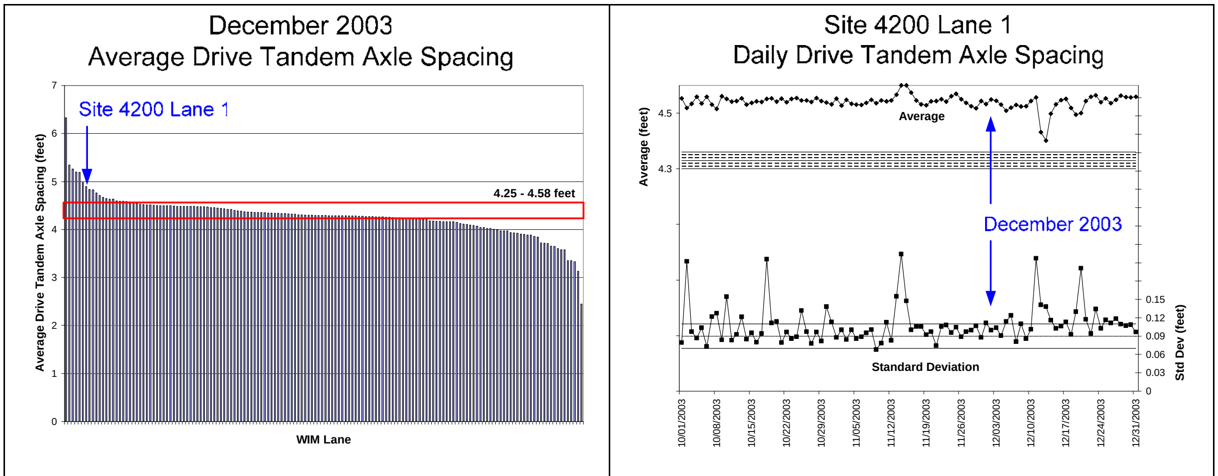
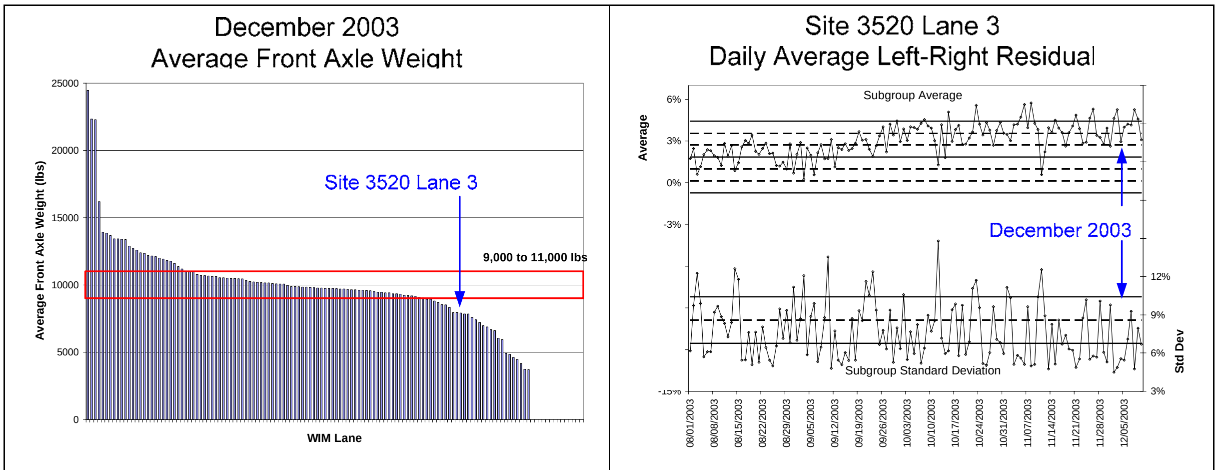


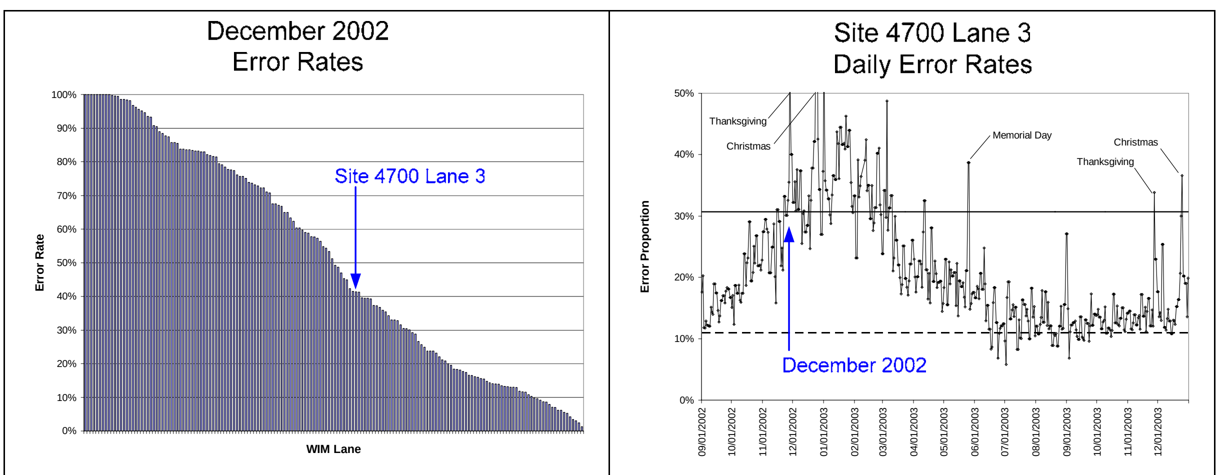
a) System Accuracy Chart | b) Statistical Process Control Chart

Figure 1. Speed Quality Control



a) System Accuracy Chart | b) Statistical Process Control Chart

Figure 2. Weight Quality Control



a) System Accuracy Chart | b) Statistical Process Control Chart

Figure 3. Error Rate Quality Control