TECHBRIEF

WIM Scale Calibration:

A Vital Activity for LTPP Sites

Publication No. FHWA-RD-98-104
FHWA Contact: Monte Symons, HNR-30 (703) 285-2730

Introduction

Long-Term Pavement Performance (LTPP) data are the foundation for new pavement designs for years to come. As such, data collected at LTPP test sites need to be as accurate and complete as possible. For the collection of truck weight data, this requires direct calibration of weigh-in-motion (WIM) scales at LTPP test sites. The purpose of this TechBrief is to highlight the significance of scale-calibration error on LTPP data, to describe the drawbacks of auto-calibration techniques currently used by some States to offset calibration errors, and to provide recommendations for implementing direct WIM scale calibration. This TechBrief is based on preliminary work to develop a calibration/commodity study.

Effects of Scale-Calibration Error

Current design procedures compute equivalent single-axle loads (ESALs) from measured axle weights using a mathematical formula developed from the American Association of State Highway Officials (AASHO) Road Test. The fourth-order relationship in this formula heavily magnifies the effects of poor scale calibration, which can lead to significant errors in determining the load experienced by a pavement and thus computing the expected pavement life.

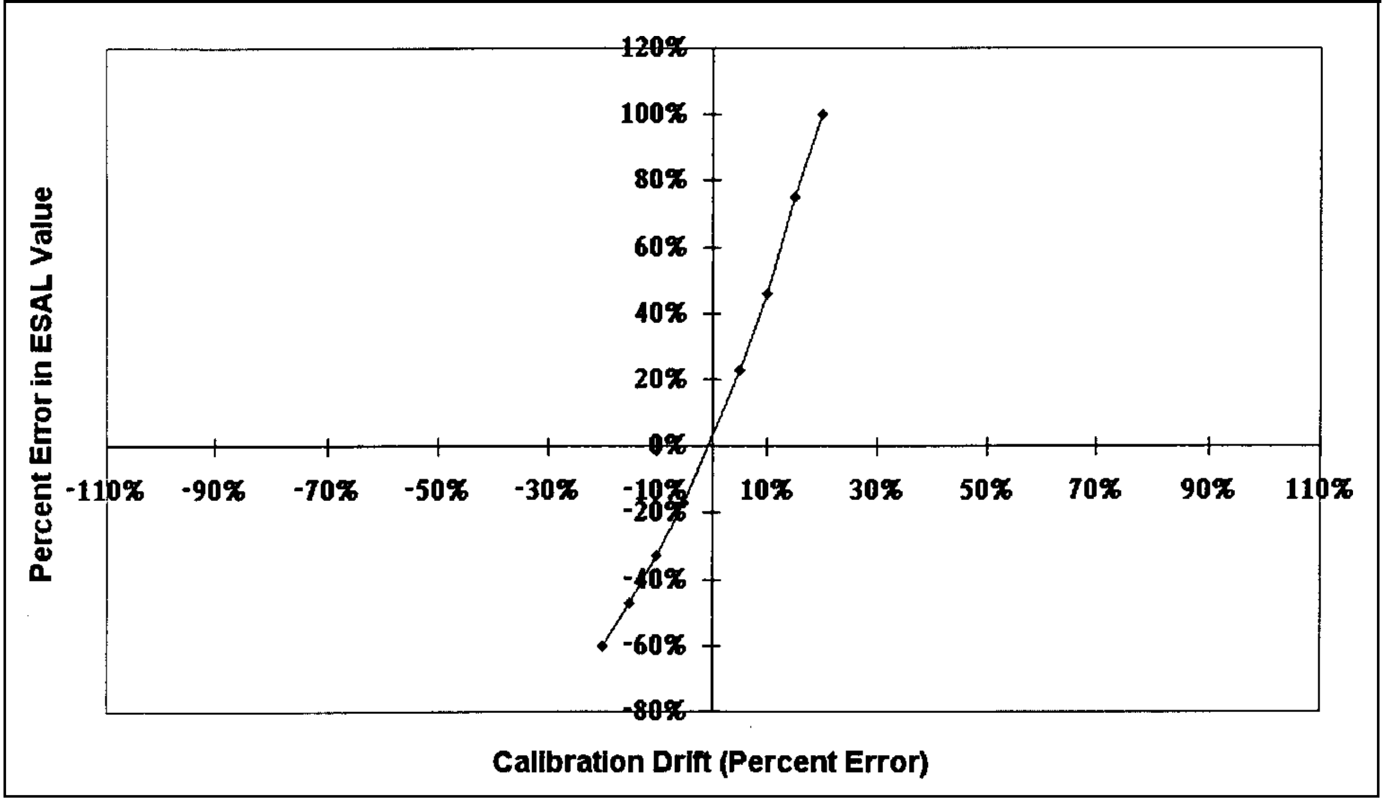
Figure 1 (on the following page) shows the general effects of scale-calibration error on the computation of ESAL values. Although the effect of scale drift varies somewhat from site to site, the basic trend is that every 1 percent error that a scale is under-calibrated results in slightly more than a 3-percent under-estimation of the true ESAL value. (ESALs computed for heavy axles are affected more by calibration drift than ESALs computed for light axles. So the ESAL error for a site with lots of heavy axles is greater than the error for a site with mostly light axles.) Every 1-percent over-estimation in axle weight represents a 4.5-percent over-estimation of ESAL values. Thus, even an over-calibration of only 10 percent would result in a 45-percent error in estimated damage.

The Long-Term Pavement Performance (LTPP) program is a 20-year study of inservice pavements across North America. Its goal is to extend the life of highway pavements through various designs of new and rehabilitated pavement structures, using different materials and under different loads, environments, subgrade soil, and maintenance practices. LTPP was established under the Strategic Highway Research Program, and is now managed by the Federal Highway Administration

U.S. Department of Transportation
Federal Highway Administration

Research and Development
Turner-Fairbank Highway
Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

Figure 1. Relationship between calibration drift and error in ESAL computations.



Drawbacks of Auto-Calibration Techniques

Many States attempt to work around the cost of scale calibration by relying on a variety of auto-calibration techniques provided by WIM equipment vendors. Auto-calibration is the practice by which software calculates and applies an adjustment to the scale calibration factor. It is based on a comparison of the average of a number of measurements of some specific variable against its expected value. Some of these techniques adjust scale-calibration factors to known sensitivities in axle sensors for changing environmental conditions, "known" truck conditions, and equipment limitations. Common techniques embedded in WIM software include:

- Using the average front-axle weight of Federal Highway Administration (FHWA) Class 9 trucks.
- Using the average weight of specific types of vehicles (often loaded five-axle tractor semi-trailers).

Although these techniques have considerable value, they are only useful after the conditions being monitored at the study site have been confirmed.

For example, average front-axle weights for Class 9 vehicles are fairly constant (if a large enough sample is taken) at most sites. However, these weights often vary from site to site across the country or even within a State. Part of this variation is due to different weight laws and truck characteristics, and part is due to different truck loading conditions at each site.

Another large part of the variation is controlled by vehicle drivers. Most drivers of modern tractors can change the location of the "kingpin" (the point at which the semi-trailer connects to the tractor). Setting the kingpin close to the cab pulls in the trailer, reducing air resistance and improving fuel consumption. However, it also magnifies the roughness of the ride in the cab and decreases driver comfort. Setting the kingpin farther away from the cab smoothes the ride in the cab, but results in higher fuel consumption. Consequently, out on the highway, drivers tend to set the kingpin close to the cab on smooth roads where road quality is no problem. However, when road roughness begins to make a ride uncomfortable, drivers shift the kingpin farther back in order to make driving more tolerable.

If no other changes are made, simply moving the kingpin setting can shift as much as 907 kg (2000 lb) onto or away from the front axle of a fully loaded heavy truck. This is a change of 10 to 15 percent in axle weight. By not accounting for these fairly common fleet changes at a specific WIM scale location, errors can be auto-calibrated into the WIM system. In fact, LTPP has confirmed several cases in which auto-calibration settings forced scales to become uncalibrated, simply because the auto-calibration setting was incorrect for a particular site.

Auto-calibration is not, in itself, a bad idea. However, before it can be used, a State must determine the following:

- Which procedure will be used.
- Whether that procedure is based on assumptions that are true for a particular site.
- How that procedure complements the limitations in the axle sensor (and sensor installation) being used.
- Whether enough test trucks are crossing the sensor during a given period to allow the calibration technique to function as intended.

Recommendations for Direct Calibration

Only direct calibration of a WIM scale after it has been installed at a site ensures that it is measuring axle weights correctly. This includes a comparison of static axle weights with axle weights that are estimated from multiple vehicle passes with more than one vehicle. For short-duration counts, calibration should be performed immediately before the start of LTPP data collection.

For longer duration counts, the scale should be calibrated initially, the traffic characteristics at that site should be recorded, and the scale's performance should be monitored over time. The State should also perform additional, periodic on-site calibration checks (at least two per year). These steps will ensure that the data being collected for LTPP, as well as for State use, are accurate and reliable.

More information on WIM scale calibration can be found in the following documents:

1. ASTM Standard E1318-94, Highway Weigh-in-Motion (WIM) Systems With User Requirements and Test Method, Annual Book of ASTM Standards.

2. Bahman Izadmehr and Clyde Lee, "On-Site Calibration of Weigh-in-Motion Systems," Transportation Research Record 1123, Pavement Management and Weigh-in-Motion, 1987, pp. 136-144.

3. Long Term Pavement Performance Program, Protocol for Calibrating Traffic Data Collection Equipment, April 1998 (available from the LTPP team of the FHWA Pavement Performance Division).

4. "On-Site Evaluation and Calibration Procedures for Weigh-in-Motion Systems," NCHRP Research Results Digest #214, 1996.

5. Peter Davies and Fraser Sommerville, "Calibration and Accuracy Testing of Weigh-in-Motion Systems," Transportation Research Record 1123, Pavement Management and Weigh-in-Motion, 1987, pp. 122-126.

Researcher: The study on which this TechBrief is based was performed by Law PCS, 12104 Indian Creek Court, Suite A, Beltsville, MD 20705 and the Washington State Transportation Center, University of Washington, University District Building, 1107 NE 45th Street, Suite 535, Seattle, WA 98105-4631. Contract No. DTFH61-97-C-00002.

Distribution: This TechBrief is being distributed according to a standard distribution. Direct distribution is being made to the Regions and Divisions.

Availability: This TechBrief is based in part on a publication entitled, Detection of Calibration Versus Commodity Shifts, by Mark Hallenbeck and Cindy Cornell-Martinez. It was published in June 1996 by Chaparral Systems Corporation, 649 Harkle Road, Suite E, Sante Fe, New Mexico 87505, (505) 983-5594. It is available on Chaparral Systems Corporation's home page at http://www.chapsys.com//ltpp_web/ltpp7.htm.

Key Words: Weigh-in-Motion, WIM, LTPP traffic, WIM calibration.