WEIGH-IN-MOTION System Calibration

Significant importance has been placed on initial and ongoing calibration activities to ensure an adequate level of weigh-in-motion (WIM) system performance. Field calibration procedures utilize vehicles of a known weight/configuration or a random sample of vehicles from the traffic stream measured using both a WIM system and vicinity static scale to determine mean differences between the WIM system and known/static scale measurements. The WIM system is then adjusted until mean differences equate to zero. The Long Term Pavement Performance (LTPP) Program recommends repeating this field calibration procedure at least twice per year for permanent WIM systems. Alternatively or additionally, a variety of auto-calibration techniques are provided by equipment vendors that adjust for changing climatic conditions, known vehicle conditions, and/or inherent WIM equipment limitations. Secondary strategies for improving WIM system performance include multiple weight sensor installation to better compensate for dynamic loading variations and post-collection remedial data editing.

Each of the aforementioned approaches for ensuring WIM system accuracy is not without shortcoming. Field calibration procedures - which provide the best results - are costly to perform and hence, may occur infrequently. Auto-calibration procedures consider only discrete temperature ranges, require a sufficiently large and continuous sample of vehicles, do not account for site-to-site variations, may lead to a progressive drift at some WIM sites, and may cease to function if pavement conditions deteriorate. Multiple weight sensor installation can be costly with only modest gains in WIM system performance. Post-collection data editing provides only a general indication of data conformance to expected weight distributions and is not timely in flagging WIM performance problems.

During the 2006 Commercial Motor Vehicle Size and Weight Enforcement Scanning Study - sponsored by the Federal Highway Administration, American Association of State Highway and Transportation Officials, and National Cooperation Highway Research Program - a team of U.S transportation experts observed notable technology-based European calibration policies and procedures for WIM systems leading to improved data quality and enhanced efficiency and effectiveness in operations.

This informational brief describes these policies and procedures and considers the potential for U.S. application, including the necessary supporting technologies and opportunities for incremental implementation. Anticipated benefits and associated cost savings related to operational enhancements, infrastructure preservation, increased safety, and reduced congestion and harmful emissions are also described.

Requested By: AASHTO Standing Committee on Highways

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Notable Policies and Procedures

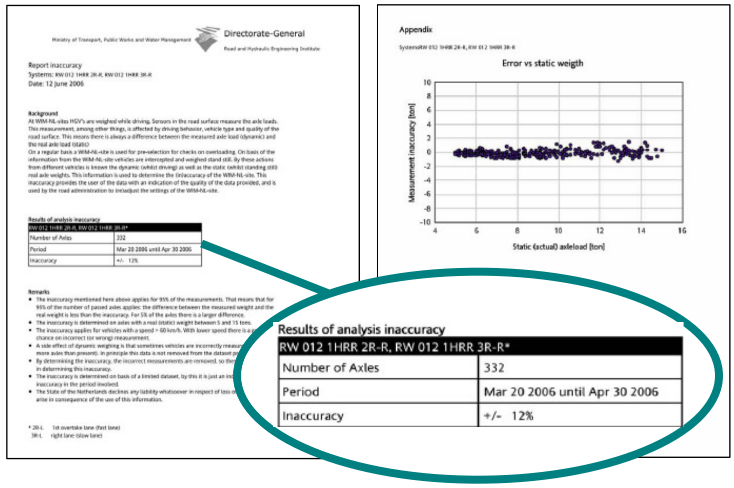
Several of the calibration procedures observed in Europe mimic those used in the U.S., including field calibration with vehicles of a known weight and auto-calibration. Unique observations included: continuous, ongoing calibration procedures performed during mobile enforcement efforts; robust quality assurance procedures; and dynamic calibration procedures, facilitated through the use of a specially-designed vehicle, that eliminate traditional dynamic-to-static measurement adjustments.

Continuous Calibration

Enforcement officials in France and The Netherlands utilize continuous, ongoing calibration procedures to ensure an adequate level of WIM system performance. Under this procedure, static axle weight records obtained by enforcement officials during their scheduled enforcement activities are directly compared for accuracy to the axle weight records captured by the WIM system for the same vehicles. Static measurements are relayed, in near real-time, to personnel at the WIM site using unique vehicle identification information (i.e., vehicle silhouette and license plate images) and dedicated, short-range communications (DSRC). If an unacceptable level of WIM data error is observed (in The Netherlands, WIM axle weight error rates cannot exceed ±15% for 95% of the aggregate vehicles measured), the problem can be quickly corrected through system calibration or other remedial action. Periodic comparisons between static and WIM system weight records can also be performed on an ongoing basis using archived data records.

Quality Assurance

As a supplement to continuous calibration procedures, transportation officials in The Netherlands issue a formal Quality Assurance Statement – that includes the number of axles measured, period of measure, and inaccuracy (compared to static weights) for every weight record and in aggregate - with every data request including routine data disseminations. Provision of this Quality Assurance Statement allows individual data users to determine the sufficiency of data quality based on their individual needs.


Ministry of Transport, Public Works and Water Management

Directorate-General

Road and Hydraulic Engineering Institute

Report inaccuracy
Systems: RW 012 1HRR 2R-R, RW 012 1HRR 3R-R
Date: 12 June 2006

Background

At WIM-NL-sites HGV's are weighed while driving. Sensors in the road surface measure the axle loads. This measurement, among other things, is affected by driving behavior, vehicle type and quality of the road surface. This means there is always a difference between the measured axle load (dynamic) and the real axle load (static).
On a regular basis a WIM-NL-site is used for pre-selection for checks on overloading. On basis of the information from the WIM-NL-site vehicles are intercepted and weighed stand still. By these actions from different vehicles is known the dynamic (whilst driving) as well as the static (whilst standing still) real axle weights. This information is used to determine the (in)accuracy of the WIM-NL-site. This inaccuracy provides the user of the data with an indication of the quality of the data provided, and is used by the road administration to (re)adjust the settings of the WIM-NL-site.

Results of analysis inaccuracy

RW 012 1HRR 2R-R, RW 012 1HRR 3R-R*	
Number of Axles	332
Period	Mar 20 2006 until Apr 30 2006
Inaccuracy	+/- 12%

Remarks

- The inaccuracy mentioned here above applies for 95% of the measurements. That means that for 95% of the number of passed axles applies: the difference between the measured weight and the real weight is less than the inaccuracy. For 5% of the axles there is a larger difference.
- The inaccuracy is determined on axles with a real (static) weight between 5 and 15 tons.
- The inaccuracy applies for vehicles with a speed > 60 km/h. With lower speed there is a g
chance on incorrect (or wrong) measurement.
- A side effect of dynamic weighing is that sometimes vehicles are incorrectly measur
more axles than present). In principle this data is not removed from the dataset p
- By determining the inaccuracy, the incorrect measurements are removed, so the
in determining this inaccuracy.
- The inaccuracy is determined on basis of a limited dataset, by this it is just an ind
inaccuracy in the period involved.
- The State of the Netherlands declines any liability whatsoever in respect of loss o
arise in consequence of the use of this information.

* 2R-L 1st overtake lane (fast lane)
3R-L right lane (slow lane)

Appendix

SystemsRW 012 1HRR 2R-R, RW 012 1HRR 3R-R

Results of analysis inaccuracy	
RW 012 1HRR 2R-R, RW 012 1HRR 3R-R*	
Number of Axles	332
Period	Mar 20 2006 until Apr 30 2006
Inaccuracy	+/- 12%

Both France and The Netherlands utilize various data filtering processes to further ensure that WIM data is of sufficient quality. In The Netherlands, speed records <60 or >150 kph (<37 or >93 mph), vehicle length records >50 m (>164 ft), and axle loads <0.05 or >30 MT (<110 or >66,140 lbs) are identified as extreme or unreasonable data records. Typically, less than 2% of data is identified as errant using these filtering processes.

Dynamic Calibration

Metrological laws and specifications are based on static weight measurements. As such, traditional WIM system calibration methods require conversion of the true dynamic load to a static measure, with a concomitant loss in accuracy.

Through a unique public-private partnership in The Netherlands, a specially-designed vehicle was developed to allow calibration of a dynamic measure to the true dynamic load. The dynamic calibration vehicle consists of a three-axle tractor and five-axle trailer; one axle is instrumented and the remaining four axles are steerable and liftable. The trailer load can be incrementally adjusted using up to 44 1,000 kg (2,204 lb) mass pieces. The dynamic calibration vehicle measures, while driving, the dynamic forces exerted on the WIM system by the instrumented axle using strain gauges. Accelerometers mounted on the axle correct for the influence of inertia from the wheels, hub, and braking system. Measurements captured by the dynamic calibration vehicle are compared with those of the in-road WIM system at speeds of 10 to 100 kph (6 to 62 mph), for axle loads between 5 to 15 MT (11,023 to 33,070 lbs), and with an accuracy of ±5%. The dynamic calibration vehicle can also be used to calibrate traditional static weigh bridges.

Supporting Technologies

In-road WIM System • Weight/Axle Sensors • Computer Interface/ PC Software	**Functions** • Measures and records axles and gross vehicle weight using piezoquartz, piezoceramic, fiber optic, or other sensor technology. **Considerations** • Provides 24/7 monitoring. • May be less accurate than traditional WIM systems (e.g., bending plate or load cell). • Lower cost supports wider implementation, greater geographic coverage. **Estimated Costs** • $9,000 - $32,500 per lane (for low-cost systems, traditional system costs are higher). • Varies based on weight sensor type, on-site communication requirements. • Requires additional, ongoing maintenance with associated costs.
Bridge WIM System • Weight (Voltage)/ Axle Sensors • Computer Interface/ PC Software	**Functions** • Measures and records vehicle weight using existing roadway structures instrumented with strain transducers or gauges. Bridge deflections are converted to weight measurements. • Measures and records axles using traditional in-road sensors or through Nothing-on-the-Road/Free-of-Axle Detector (NORFAD) systems. **Considerations** • NORFAD systems offer improved durability and easier installation with no traffic delays. • Requires suitable bridge in a location where WIM data is warranted. • Proven most successful on short, stiff bridge structures. • Structural assessments using strain data may require transducer calibration. • Calibration may require a high expertise level. **Estimated Costs** • $100,000 - $130,000 per bridge/system. • Varies based on weight sensor type, on-site communication requirements.
Vehicle Identification System • Camera/ OCR Software • DSRC/ Portable Computer	**Functions** • Captures both vehicle silhouette and license plate images using cameras. • Converts license plate image to numeric data using OCR software. • Transmits images/data via DSRC to portable computer used by enforcement officials. **Considerations** • Conversion of some license plate images to numeric data may result in errors. **Estimated Costs** • $52,000 - $80,000 per system. • Varies based on camera type, on-site communication requirements.
Archived Records Database	**Functions** • Supports data-driven scheduling of enforcement resources. • Supports data-driven preventative carrier contacts. • Supports continuous calibration and enhanced data quality. • Encourages long-term performance monitoring. **Considerations** • Requires procedures for quality control. **Estimated Costs** • $225,000 - $300,000
Dynamic Calibration Vehicle	**Functions** • Calibrates dynamic load measurements to true dynamic (rather than static) loads. **Considerations** • May be used to calibrate traditional static weigh bridges. **Estimated Costs** • $1.72 million for vehicle construction. • $6,300 per in-service day.

Perceived and Reported Benefits

Operational benefits attributable to the observed technology-based WIM system calibration policies and procedures are largely anecdotal and consider continuous, ongoing calibration benefits for quickly and cost-effectively identifying WIM system performance problems. French enforcement officials reported that a combination of WIM system auto-calibration and continuous, ongoing calibration procedures has eliminated the need for resource-intensive manual field calibration, typically conducted on an annual basis.

The enhanced weight data quality - achieved through more frequent and accurate calibration actions and quality assurance controls - has broader potential benefit across transportation

Incremental Implementation Steps

	CONTINUOUS CALIBRATION	QUALITY ASSURANCE	DYNAMIC CALIBRATION
Dynamic Calibration Vehicle			Dynamic Calibration Vehicle
Archived Records Database	Database	Database	
Vehicle Identification System	Cameras/OCR	Cameras/OCR	
	DSRC	DSRC	
Bridge WIM System	Voltage/Axle Sensors	Voltage/Axle Sensors	Voltage/Axle Sensors
	Computer Interface/ Software	Computer Interface/ Software	Computer Interface/ Software
AND/OR			
In-road WIM System	Weight/Axle Sensors	Weight/Axle Sensors	Weight/Axle Sensors
	Computer Interface/ Software	Computer Interface/ Software	Computer Interface/ Software

Weigh-in–motion data supports various applications related to planning and programming of transportation facilities, pavement design and rehabilitation, apportionment of pavement damage, compliance with vehicle weight regulations, development of geometric design standards, compliance and regulatory policy development of vehicle dimensions, safety analysis, traffic operation and control, and analysis related to highway bridges.

Interface with Other Functional Areas

SUPPORTING TECHNOLOGIES	ENFORCEMENT								WIM SYSTEM CALIBRATION			OS/OW PERMITTING			BRIDGE PRESERVATION		
	SIZE			WEIGHT													
	Infrastructure Preservation	Pre-selection	Direct Enforcement	Pre-selection	Resource Scheduling	Preventative Carrier Contacts	Direct Enforcement	Bypass Prevention	Continuous Calibration	Quality Assurance	Dynamic Calibration	Self Permitting/Routing	Bridge Safety Assessment	Remote Field Verification	Structural Assessment	Safety Assessment	Load Testing
Overheight Vehicle Detection System	✓	✓															
Vehicle Profiler System			✓														
In-road WIM System				✓	✓	✓	✓	✓	✓	✓	✓			✓			
Bridge WIM System				✓	✓	✓		✓	✓	✓			✓	✓	✓	✓	✓
Dynamic Calibration Vehicle											✓						
Vehicle Identification System	✓	✓		✓		✓	✓	✓	✓	✓				✓			
Advanced Routing/Permitting System												✓					
Archived Records Database					✓	✓			✓	✓			✓		✓	✓	