TEST SITE FOR EVALUATION OF HIGH-SPEED WIM AND ITS SOLUTIONS IN BRAZILIAN CONDITIONS

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Abstract

The Brazilian Federal Department of Transportation Infrastructure (DNIT) and the Transportation and Logistics Laboratory at the Federal University of Santa Catarina (LabTrans / UFSC) launched a comprehensive project for the evaluation of high-speed weigh-in-motion (HS-WIM) systems in Brazilian conditions. This paper presents an assessment of aspects related to implementation, integration, and operation of HS-WIM systems and other ITS solutions for a number of desired applications in the Brazilian federal road network. Based on developments and field observations a set of recommendations are drawn for the use of WIM in Brazil.

Keywords: Intelligent Transportation Systems, ITS, Weigh-in-Motion, WIM, Brazil.

Resumo

O Departamento Nacional de Infraestrutura de Transportes (DNIT) e o Laboratório de Transportes e Logística da Universidade Federal de Santa Catarina (LabTrans/UFSC) lançaram um abrangente projeto para a avaliação de sistemas de pesagem em movimento em alta velocidade (HS-WIM) em condições brasileiras. Este trabalho apresenta a avaliação de aspectos relacionados à implantação, integração e operação de sistemas HS-WIM e outras soluções de ITS para diferentes aplicações na malha rodoviária federal brasileira. Baseado em desenvolvimentos e observações de campo, uma serie de recomendações são elencadas para a utilização de sistemas WIM no Brasil.

Palavras-chave: Sistemas Inteligentes de Transportes, ITS, Pesagem em Movimento, WIM.

1. Introduction:

The increasing volume of heavy vehicle traffic and the limitations in human resources have motivated the Brazilian federal government to promote developments that gradually allow for higher levels of automation in weight enforcement and traffic data collection processes adopted in the Brazil. In this context, several efforts have been carried on by DNIT and LabTrans/UFSC in order to support the implementation of WIM in the country.

In the end of 2013 a research project was launched for the evaluation of HS-WIM in integration with other ITS technologies. For this project, a test site was built over a 200 meter stretch of road BR-101 SB, in the municipality of Araranguá, Brazil. The developments and evaluations in context of the project were also performed with a legacy test-site implemented in 2009 for studies on multiple-sensor WIM and situated in the same area.

This project takes into consideration the following potential applications of WIM in Brazilian conditions:

- Traffic data collection
- Pre-selection for overloading enforcement
- Company Profiling.

International experience shows that different local conditions, such as pavement structure, climate, traffic and vehicle fleet, may influence in the overall performance of WIM systems. Hence, one of the objectives of the project is to provide an assessment of the performance of WIM systems in terms of measurements, durability and consistency of operation. The second goal of the project is to evaluate the performance and feasibility of WIM systems in integration with different ITS solutions for applications in overload control.

2. Test-site Layout

Figure 1 presents the layout of the test-site built specifically for the project, where the implementation of two complete HS-WIM systems and related ITS solutions took place:

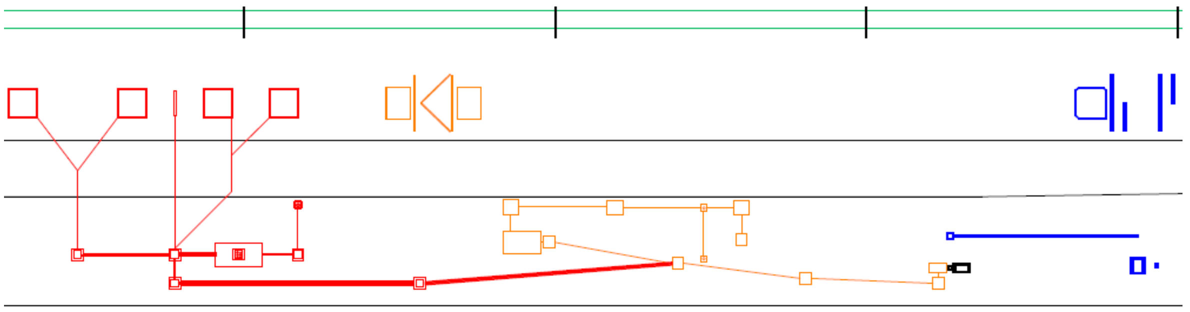

Figure 1 – BR-101 test-site layout

The drawing shows the implementation of three complete technology solutions from different suppliers, as described in the list below:

- **Blue:** Intercomp – HS-WIM.
- **Orange:** Sterela/Egis – HS-WIM and Automatic License Plate Reader (ALPR).
- **Red:** IIS – Vehicle Waveform Identification (VWI), ALPR and automatic code reader for the National Registry of Freight Motor Carriers (RNTRC).

2.1 WIM systems

Two WIM solutions were deployed specifically for the project. The first is composed by strain gauge based strip sensors manufactured and supplied by Intercomp. The second is composed by piezo-quartz sensors manufactured by Kistler and supplied by Sterela/Egis.

Another set of WIM sensors were used in the context of the project. These were previously installed for a multiple sensor experiment, and include the following sensor technologies:

- Piezo-quartz, supplied by Kistler.
- Piezo-ceramic, supplied by Electronique Controle Mesure.
- Piezo-polymer, supplied by Measurement Specialties.
- Fiber optic, supplied by Measurement Specialties.

This WIM site is built in parallel with the BR-101 road, and was originally implemented in 2009. The installation can be visualized on Figure 2.

Figure 2 – LabTrans MS-WIM test site

2.2 ITS solutions

The integration of WIM with other ITS solutions is essential for all applications envisioned for supporting overload control in the Brazilian federal road network. Thus, the project included the integration of WIM with the following technologies:

- Automatic license plate reader (ALPR)
- Vehicle waveform identification (VWI)
- Automatic RNTRC code reader.

Currently, ALPR cameras provide the only universal source for automatic vehicle identification in Brazil, and therefore are essential for both weigh station pre-selection and company profiling applications. At weigh stations, HS-WIM systems require ALPR for automatic escape detection in cases where potentially overloaded vehicles refuse to enter the enforcement site. For company profiling, ALPR allows the identification of the carrier and subsequent actions for overloading control.

The RNTRC code reader was installed with the objective of testing a different source of vehicle identification, given the importance of this function in the envisioned processes for overloading control. However, currently the RNTRC code does not cover the entire heavy vehicle fleet as it has been only implemented in commercial vehicles.

Finally, the VWI systems provide a means for vehicle identification and recognition besides the automatic license plate readers. For instance, in an automatic weigh station program such as the recently launched Automated and Integrated Enforcement Stations (PIAFs), vehicles need to be recognized in two situations:

- Matching pre-selection records with enforcement records for calibration assessment
- Matching pre-selection records with vehicle records for escape detection.

Both functions were implemented and tested in the context of the test track.

2.3 Enforcement Weigh Station

In order to evaluate the application of the HS-WIM test site for pre-selection of potentially overloaded heavy vehicles, two extra data collection points were installed at DNIT 1608 fixed weigh station, located about 2,000 meters downstream traffic in the same road. These data collection sites are equipped with VWI sensors and overview cameras, which allow for the recognition of vehicles in different points of the enforcement station after they run through the HS-WIM test-site. Figure 3 shows, in red, the installation layout of these systems within the enforcement station area.

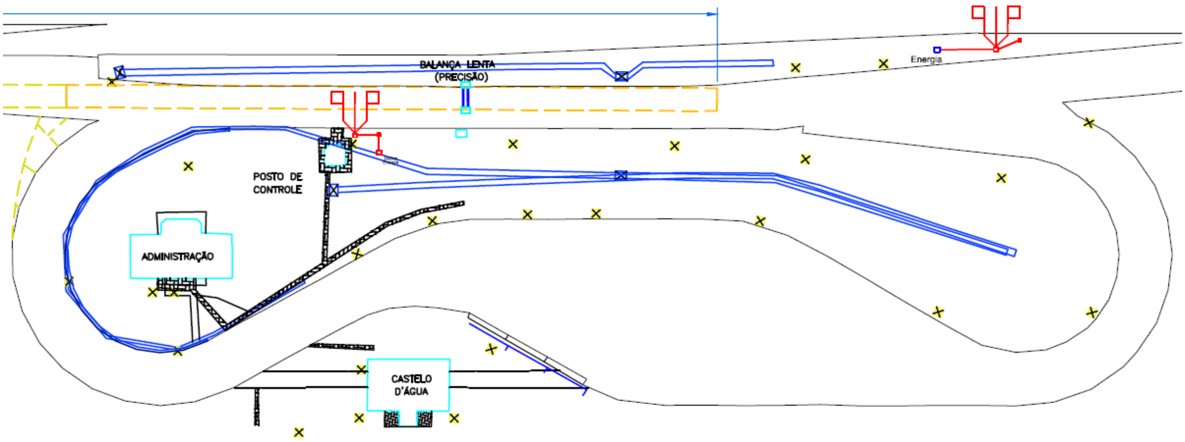

Figure 3 – VWI implementation at 1608 enforcement weigh station

In addition to allowing the assessment of HS-WIM as a pre-selection tool in automated weigh stations, the installation of the VWIs provide a reliable way for matching the high-speed WIM measurements with the low-speed precision measurements performed inside the enforecement station, thus alowing the comparision and constant performance evaluation of the HS-WIM systems. Antennas for wireless communication provide the communication between the 3 data collection points.

3. Project Execution

The stages for the execution of the project include:

- Implementation.
- Development and integration.
- Performance assessment.

3.1 Implementation

For the purpose of the project and the installation of WIM sensors, DNIT and LabTrans/UFSC designed and implemented a specific road stretch with approximately 200 meters of pavement, built with more robust capabilities than conventional asphalt pavements on the Brazilian federal highway network. Previous experience with WIM in Brazil shows a high probability of early deterioration of pavement and grouting around sensors installed on conventional asphalt pavements. Thus, a specially designed road stretch was implemented for testing and potential replication. The intervention for the construction works were done simultaneously with another construction project taking place on the same road. This simultaneous intervention provided with savings in resources, which can be possibly replicated in future WIM projects in Brazil.

Figure 4 shows a comparison between the new structure designed specifically for the project and the existing structure of the same highway:

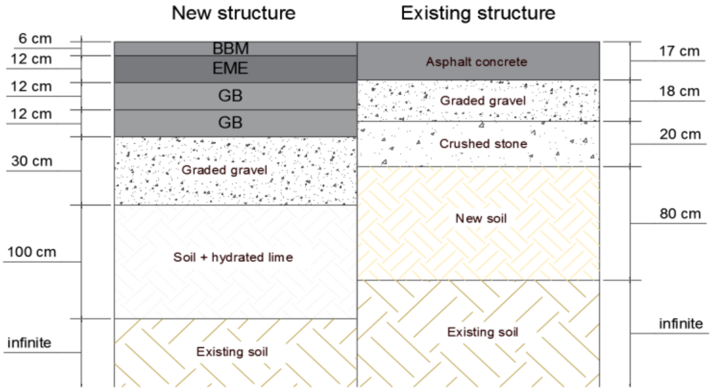

Figure 4 – Comparission of new and existing pavement structures

While the original pavement was designed according to DNIT's pavements manual (DNIT, 2006), the new pavement considers the French manual for pavement formulations (LCPC, 2007) and aims to provide an adequate structure for the installation of WIM sensors. The end result seen on Figure 4 shows a significant difference in the asphalt layers and overall depth of the structures.

For the implementation of WIM systems and other ITS solutions, conventional methods were evaluated and implemented in local conditions for cost reduction and ease of replication. Figure 5 shows the final result of the new WIM installations, with the Intercomp system (on the left) and the Sterela/Egis system (on the right).

Figure 5 – WIM installation

3.2 Development and integration processes

The aspects related to development and integration within the project included the following activities:

- Development of a HS-WIM system with existing sensor installations and locally available components.
- Development of vehicle classification system for the Brazilian heavy vehicle class scheme.
- Integration of WIM with other ITS systems.

3.2.1 *HS-WIM system development*

LabTrans/UFSC developed its own HS-WIM system with the objective of providing a reproducible methodology, which can be implemented with the use of existing sensor technologies and components available in the local market. In its core the development of the weighing algorithm started with a manual provided by the WIM sensor manufacturer Kistler (Kistler, 2004).

In this system, signal acquisition is made by two acquisition boards controlled by a local server. Quartz sensors are connected to a charge amplifier and fiber-optic sensors have a signal transducer. Ceramic and polymer sensors are connected directly to the acquisition board. After applying the filter to the signals, the algorithm implemented calculates the weight for each sensor and uses the mode to purge outlier measurements. An example of collected and filtered signals piezo-ceramic sensors is shown in Figure 6.

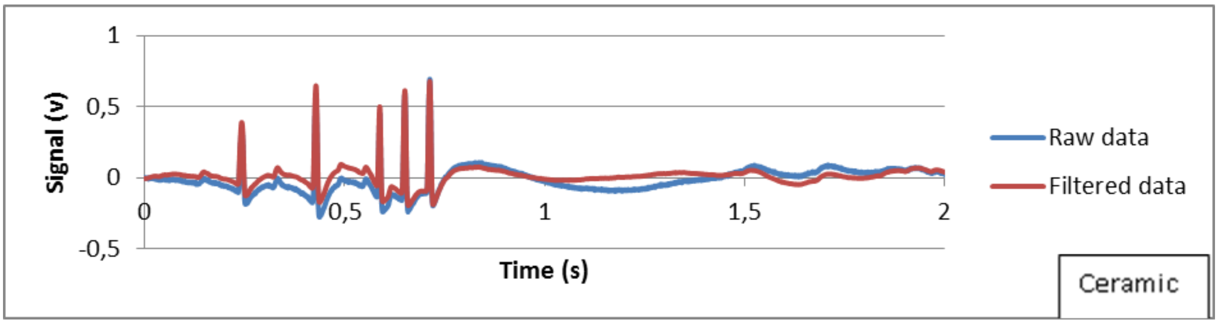

Figure 6 – Sensors raw data comparison to filtered data

3.2.2 *Vehicle classification system development*

The heavy vehicle class division used for weigh enforcement in Brazil includes over 120 different heavy vehicles classes, with class-related load limits (DNIT, 2012). The class division is based on the axle distances, axle type and vehicle length. The development and evaluation of vehicle classification systems have been carried by partner companies with the support of LabTrans/UFSC.

Currently, classification has been implemented on a limited basis, where groups of classes are assigned for each vehicle run. A full classification system will be implemented in partnership with the development team at Sterela/Egis, with the inclusion of dual tire detection as a variable for dividing the groups of classes and assigning one specific class for each vehicle run. This variable is already detected with the use two strips of piezo-polymer sensors angled at a specific degree. The identification of all truck classes is necessary as each specific class has its own specific overloading penalty criteria.

3.2.3 *Integration of WIM with other ITS systems*

The integration of WIM with related ITS solution was performed at different levels in order to allow a full assessment of the use of WIM for different applications within the project. As a final step for the integration processes, the platform Smart Roadside Inspection System (SRIS) was implemented in order to provide a full integration of the systems and the respective data collected. Figure 7 shows the user interface provided by SRIS, emulating a fixed weigh station application with the integration of WIM and vehicle identification systems:

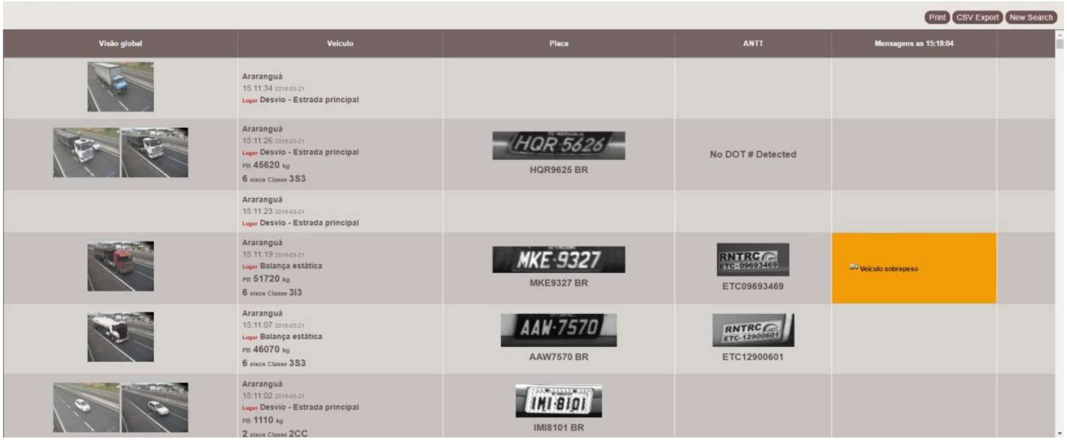

Figure 7 – SRIS integration platform

3.3 Performance assessment:

The performance assessments in the context of the project are done for the following individual aspects:

- Physical conditions of installations.
- HS-WIM measurements.
- Vehicle classification.
- Vehicle identification by ALPR and RNTRC code reader.
- Vehicle recognition by VWI systems.

The physical and operational conditions of the installations remained stable throughout the execution of the project, with the exception of the WIM systems installed over regular pavement on the legacy MS-WIM site. Figure 8 shows an example of deterioration of the WIM installations on the legacy MS-WIM test-site

Figure 8 – Pavement deterioration of MS-WIM site

The assessments of HS-WIM measurements were based on methods and recommendations present on COST 323 (2002). The evaluations were performed with the aid of a LS-WIM enforcement system, which was has been used as a reference for the evaluation of the high-speed measurements. Table 1 summarizes the results with the strain gauge and piezo-quartz HS-WIM systems implemented on the BR-101 highway:

Table 2 – Performance of WIM systems

WIM result	Test conditions	Period (after calibration)
A(5)	R1 (I)	1-2 months
B+ (7)	R1 (I)	2-3 months
B(10)	R2 (II)	12 months

The strain gauge and piezo-quartz HS-WIM solutions implemented on BR-101 were evaluated over 12 months for GVW measurements. Both systems presented performance A(5) in the first month and B(10) in the last month of evaluation. The first three months of operation were assessed under limited reproducibility conditions (R1) and environmental repeatability (I), and the results ranged between A(5) and B(7) in these tests. The remaining of the months included tests under full reproducibility conditions (R2) and limited environmental reproducibility (II).

Class C(15) was temporarily tested when the road surface area deteriorated around the strain gauge system but it returned to perform on class B(10) after the situation was solved. So far, the results on axle loads and axle group loads are not conclusive and further evaluation will provide a more precise assessment. This has been prevented by an incompatibility in the output format of the systems, which should be solved upon the completion of the project.

The HS-WIM solution developed by LabTrans/UFSC with the use of piezo-quartz sensors have shown compatible results with the commercial solutions in the terms of GVW measurements in the tests performed two weeks after calibration, as shown on Table 1:

Table 3 – Performance assessment of LabTrans/UFSC HS-WIM system

WIM result	Test conditions	Period (after calibration)
A(5)	R1 (I)	2 weeks
D+ (20)	R2 (II)	12 months

The system was tested on class A(5) for GVW measurements in its first assessment. Twelve months later, mostly due to poor pavement conditions over the legacy MS-WIM test site, the system’s performance had deteriorated to class D+ (20).

The assessments over vehicle classification, vehicle identification and vehicle recognition performances have not yet been done individually, and it will be addressed within the start of 2017.

4. Results and recommendations

- **Implementation:** Pavement design and construction constitutes a vital process for the implementation of WIM systems in Brazilian conditions. As well, timing of the construction processes is important in order to reduce costs and minimize disruptions in the traffic flow

- **Implementation:** A more widespread adoption of WIM applications in Brazil may be achieved if the main challenges to implementation are successfully addressed: high costs for pavement works and system acquisition; large and growing number of heavy vehicle classes and respective load limits; limitations in vehicle identification due to poor plate conditions and reflectivity standards
- **Integration:** Integration among WIM and other ITS systems allows for applications such as automatic pre-selection at weigh stations and company profiling. Reliable technologies for vehicle recognition are especially important for applications of WIM in the context of automated fixed weigh stations
- **Development:** Despite the large number of heavy vehicle classes Brazil, the developments over vehicle classification based on axle configuration have shown promising results over the most representative vehicle classes. The addition of dual tire detection to the measurements of axle count and distances may provide the necessary standards for automated enforcement processes
- **Development:** Measurement performance of WIM systems in Brazilian conditions showed to be satisfactory provided the existence of an appropriate pavement structure for the installation. Systems may be developed in Brazil by the integration of existing sensor technologies with components available in the local market
- **Performance assessment**: Individual performances on vehicle classification, vehicle identification and vehicle recognition will be assessed within the conclusion of the project.

5. Conclusions

A comprehensive project was launched by LabTrans/UFSC and DNIT for the evaluation of high-speed WIM and ITS solutions in Brazilian conditions. The results of the project have been used as recommendations for the Automated and Integrated Enforcement Stations (PIAF) and the National Plan on Traffic Count (PNCT), which together will account for the implementation of over 350 WIM sites in Brazilian federal road network.

Over the course of the project, different WIM systems and sensor technologies were implemented and integrated with other ITS technologies, allowing for an assessment of different applications related to overload control. Different aspects of implementation and operation of the systems have been developed and evaluated, so recommendations could be drawn, providing subsidy for a more widespread use of WIM systems in Brazil.

The expected future results include a full assessment of the capabilities of the systems installed for each envisioned application, providing subsidy for future WIM implementation in Brazil.

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