DNIT TECHNOLOGICAL MODEL FOR DIRECT ENFORCEMENT ON BRAZILIAN FEDERAL HIGHWAYS

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Abstract

The National Department of Transport Infrastructure (DNIT), part of Brazil's Ministry of Infrastructure (MInfra), has plans for implementing high-speed weigh-in-motion (HS-WIM) for direct enforcement of oversized and overloaded vehicles. Since the 1980s, DNIT has used weight stations for overload enforcement, and in 2014 it launched the Integrated Automated Inspection Station model. Recently, DNIT started a new program for direct enforcement on highways called the Mixed Weigh Station (PPM). The PPM is composed of the On-Road Control Station (ECP) and a Mobile Operations Unit (UMO), both connected to an Operational Control Center (CCO). The PPM program has various functionalities, including automatic vehicle identification, automatic license plate recognition, pre-selection, vehicle classification, data traffic counting, dimensions, and detection of excess height for vehicle classification. DNIT has plans to use the WIM installation for direct enforcement after receiving metrology certification of the WIM system for direct enforcement and meeting all legal requirements. By mid-2024, it is expected that WIM will be allowed to operate for direct enforcement in Brazil.

Keywords: Weigh-in-Motion, Weigh Station, Direct Enforcement, Overload, Technology, Model, Highway.

1 Introduction

The National Department of Transport Infrastructure (DNIT), a division of the Ministry of Infrastructure (MInfra), has been actively working to implement high-speed weigh-in-motion (HS-WIM) technology for direct enforcement of oversized and overloaded vehicles. DNIT has been a pioneer in Brazil in researching and developing WIM applications for federal highways and has been using weight stations (PPV) for overload enforcement since 1980. The initial approach used WIM for pre-selection at speeds of up to 60 km/h and LS-WIM for enforcement at speeds of up to 10 km/h. DNIT is responsible for overseeing over 50,000 km of highways within Brazil's road network.

In 2014, DNIT launched the Integrated Automated Inspection Station model (PIAF), which automated traditional weighing stations by using the HS-WIM system for pre-selection (class B(10), COST-323). In 2021, DNIT introduced a new program for direct enforcement on highways called the Mixed Weighing Station (PPM), which relies on an HS-WIM system for pre-selection and a mobile operations unit for enforcement.

The PPM consists of the On-Road Control Station (ECP) and a Mobile Operations Unit (UMO), both of which are connected to an Operational Control Center (CCO) where a federal agent can take action with overloaded vehicles (as shown in Figure 1). DNIT has designed the PPM operation to meet international specifications such as COST 323 (2002) and OIML-R-134-1-9 (2006).

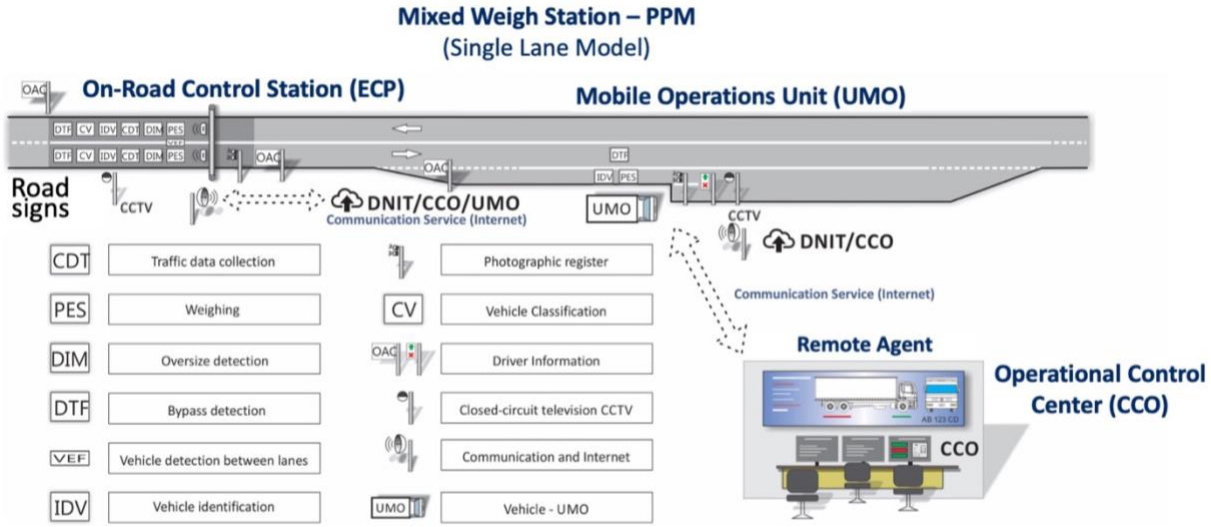

Figure 1 – DNIT technological model of a Mixed Weighing Staion (PPM)

The PPM program is a temporary measure that DNIT plans to use until HS-WIM is no longer not allowed from conducting direct enforcement. Once the WIM system receives metrology certification for direct enforcement and fulfills all legal requirements, DNIT intends to utilize the WIM installation for direct enforcement, allowing the mobile operations unit to operate in a different location on the road network. The expectation is that by mid-2024, WIM will be permitted to operate for direct enforcement. However, discussions are ongoing regarding the type of message to be communicated to the driver and the method of verifying that an

overloaded vehicle has adjusted its weight. According to CONTRAN Resolution No. 526/2015, vehicles with an axle weight exceeding 12.5% must unload their cargo.

2 Brazil plans for direct enforcement

On January 12, 2022, the National Institute of Metrology, Quality and Technology (INMETRO) published Ordinance No. 019 that approves the consolidated Metrological Technical Regulation for automatic weighing instruments for road vehicles in motion. The INMETRO Ordinance has three classes for gross vehicle weight (initial-verification: 2.5%, 3.5% and 5%; in-service: 5%, 7% and 10%) and three classes for axle and group of axles (i-v: 4%, 6% and 8%; i-s: 8%, 12% and 16%).

MInfra's plans are to create an integrated network of different types of equipment (Figure 2) such as traditional weighing stations, weighing stations with HS-WIM, traffic data collection systems, speeding violation enforcement systems, among others, in order to improve safety, preserve road infrastructure, and enhance competitiveness in transportation. Integrating the data gathered by various systems into an Information Data Center will facilitate obtaining diverse information, including but not limited to traffic and transportation data collection, commercial transport intelligence and data, enforcement of over-sizing and overloading, statistical information, traffic indicators, identification of new sites for overloading enforcement, and other relevant types of information.

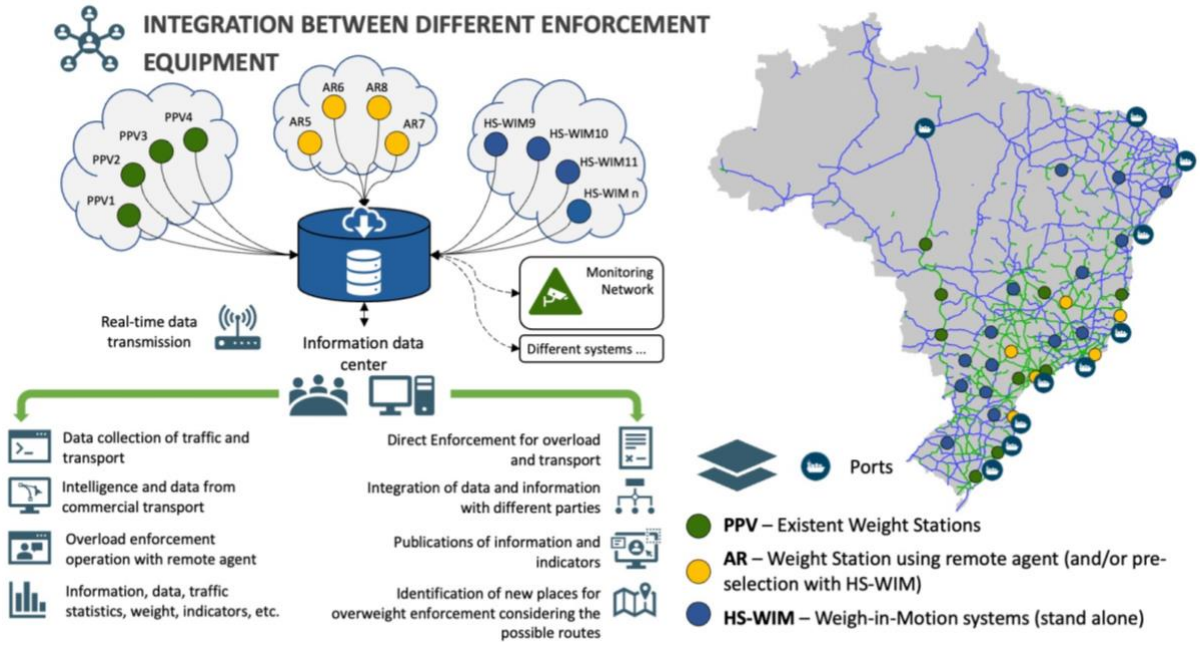

Figure 2 – Experimental site instrumentation design with WIM system and the groups of geophones

The operational architecture design (Figure 3) takes into account that the HS-WIM (ECP) system on the road communicates with the UMO in "real-time", transmitting vehicle identification, images, classification, dimensions, weight, and other information from each vehicle passing on the road. The federal agent, situated at the operational control center, receives all data from both ECP and UMO and takes actions to determine the type of violation

and to carry out administrative operations such as unloading or balancing the cargo. All this information is then forwarded to transportation management, the police, and the MInfra database.

Figure 3 – Operational architecture design

3 Definition of locations for implementation of enforcement systems

The indication of the local where the PPM should be located is done with the help of the weighing station location tool developed by DNIT, in cooperation with the Federal University of Santa Catarina (UFSC), and LabTrans. The tool analyzes the contribution of heavy vehicle flows on the roads that make up the main logistics corridors of the federal network. The result of this analysis is the indication of locals where enforcement has the greatest potential effectiveness.

The choice of the segment where the ECP should be installed within the location indicated by the tool takes into account the following criteria:

- Length of at least 110 meters with a longitudinal slope that allows the execution of the Thick Asphalt Concrete Pavement (TACP) section.
- Length of at least 110 meters with a horizontal curve radius greater than 1000 meters.
- Presence of electrical power nearby to supply the electrical devices of the ECP.
- For segments where enforcement is indicated in both directions of the road, the ECP should be located in the same place for both directions in order to reduce installation costs.

The selection of locations where the UMO will operate, within the segments indicated by the tool, takes into account the following criteria:

- Presence of a lateral area next to the shoulder that allows the UMO to park next to the location where the scale will be positioned.
- Presence of a shoulder or acceleration/deceleration lane with a width greater than or equal to 2.00 m for the positioning of the portable scale.

- When the shoulder is not wide enough for the positioning of the portable scale or when there is no shoulder, the lateral area must have sufficient space for the positioning of the UMO and the scale, as well as a paved bed with adequate resistance for the effective functioning of the scale.
- Preferably, the highway section should be a tangent with a radius greater than 2 km, in order to facilitate the visibility of vehicles from both sides.
- Distance of 200 m to 6 km from the ECP, in order to enable the driver to understand the orientation signage for the entrance to the weighing location.
- Absence of relevant escape routes between the UMO and its respective ECP.
- Indication of a location for the installation of the ECP and operation of the UMO within the same federal unit, in order to simplify the inspection and contract management.

4 Features of the Mixed Weigh Station (PPM)

The set of sensors and peripheral equipment has been defined to fully identify the vehicle for direct enforcement. The operation of the PPM model must adhere to CONTRAN Resolution No. 902/2022, which provides the data types for integrated automated systems for measuring the weight and dimensions of vehicles, dispensing with the need for transit agents in person and thus allowing remote data collection that is valid for legal action.

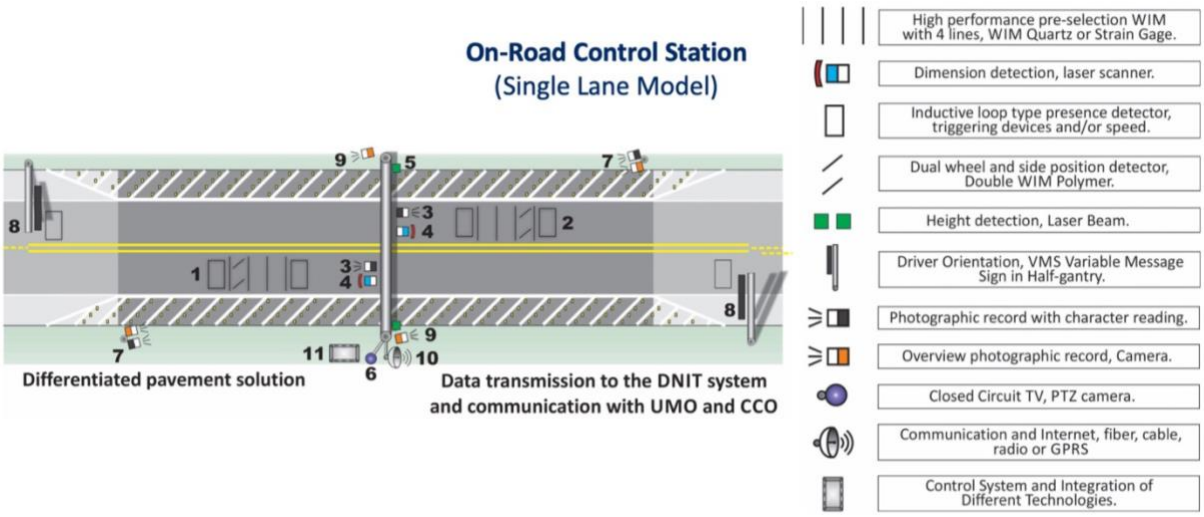

Figure 4 – On-Road Control Station features for a single-lane model

The technical solution includes the following functionalities:

- Automatic vehicle identification using Automatic License Plate Recognition (ALPR).
- Pre-selection (that meets OIML class 5E): high-performance HS-WIM system for all lanes.
- Vehicle classification.
- Data traffic counting (statistical GVW and axle weight, speed measurement, volumetric counting, classification counting).
- Dimensions and detection of excess height for vehicle classification.

- Vehicle detection bypassing the system and photo record of vehicles traveling between lanes detection and vehicles traveling in the left lane or on the wrong side.
- Driver orientation and information with Variable Messaging Sign (VMS)
- Communication service and control system integrating of the different functionalities.

As depicted in Figure 4 for the single-lane model and Figure 5 for the two-lane model, the high-performance HS-WIM system comprises four lines of WIM sensors utilizing quartz, strain gauge sensors, or similar technology, as well as two lines of WIM sensors (angled to the direction of the road) utilizing polymer, ceramic, quartz, strain gauge, or similar technology. The system is activated by inductive loops, with one loop situated at the entrance and another at the exit of the pre-selection WIM area. Cameras equipped with ALPR capture images of the front of the vehicle, targeting the license plate in both directions of the highway, and read the alphanumeric characters.

Laser scanners measure the vehicle's dimensions in both directions of the road. Vehicle length is a requirement for vehicle classification, which is based on the number of axles, distances between axles, and total length. Brazil has more than 180 classes of heavy vehicles (including buses). The excess height detection system uses an Optical Barrier type sensor. A PTZ-type IP camera is used to monitor the weigh operation at the ECP. There is a bypass detection system to survey vehicles traveling in the wrong direction and passing between the lanes. The driver information system consists of a VMS in a gantry for each direction of traffic. Two panoramic cameras register the offending vehicles and record the moment of activation of the VMS. There is a direct link of communication between the ECP and the UMO, and an internet connection to the operational control center at the DNIT Headquarters.

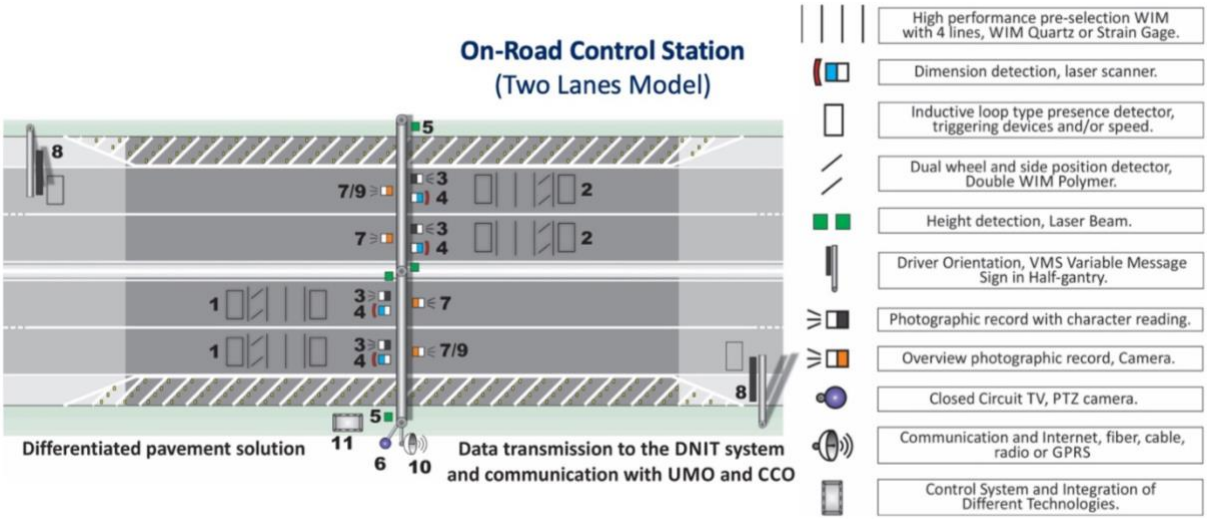

Figure 5 – On-Road Control Station features for a two-lane model

Each UMO consists, at minimum, of the following equipment and service families: portable weighing system, driver guidance system, monitoring camera (PTZ), lighting system, communication system with the CCO and ECP, monitoring and enforcement system, management and control system, signaling and safety equipment, and a van-type vehicle.

The portable static weighing scales with Model Approval Certificate from the National Institute of Metrology, Quality and Technology (INMETRO), with a minimum capacity of 20,000 kilograms shall contains a digital display, capacity of measuring the weight of each wheel of the heavy vehicle axle, with software licensed by the manufacturer, capable of operating on any firm, smooth, and level surface. The complete set necessary for operation must be made available, including a leveling conveyor made of high-strength material to allow for perfect wheel leveling, sufficient batteries for operations, a set of cables for interconnection between the scales, and battery chargers (Figure 6).

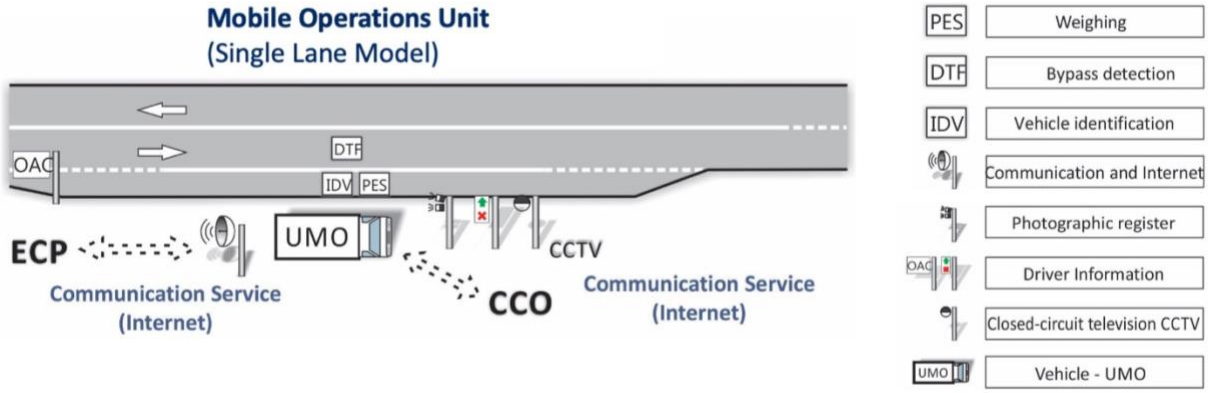

Figure 6 – Mobile Operations Unit features

Each CCO consists of, at a minimum, the following equipment and service families: CCO operation and a management and control system. A federal authority, represented by a federal agent, can supervise multiple PPMs 24 hours a day, 7 days a week. The federal agent is solely responsible for processing all information and proceeding with penalization. All infractions are registered by the federal agent on the National Register of Traffic Infractions (RENAINF). This is a system coordinated by the National Department of Transit (DENATRAN) that records traffic violations committed in a federal unit other than the one where the vehicle is registered and licensed. It is through RENAINF that the enforcing agency obtains the necessary data to notify the vehicle owner about the committed infraction and the respective penalty, as well as to link existing debts to the vehicle registration at DETRAN.

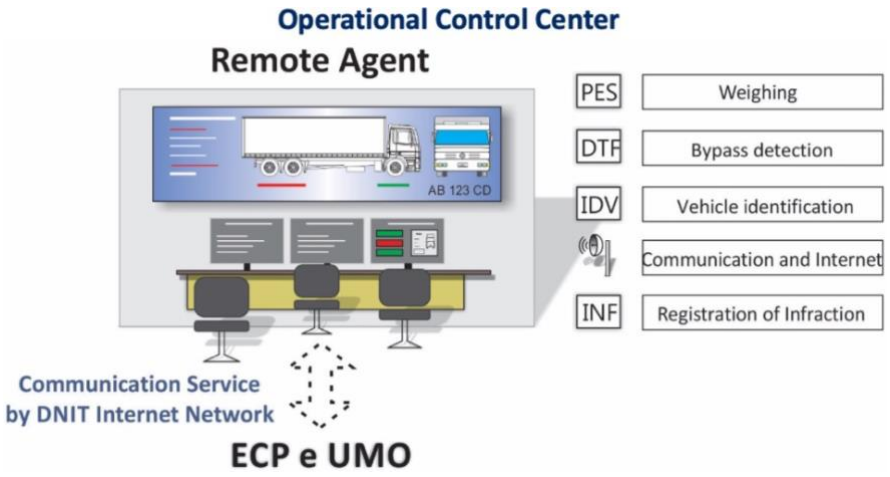

Figure 7 – Mobile Operations Unit features

5 Pavement design for HS-WIM

A Thick Asphalt Concrete Pavement (TACP) was designed to the necessary requirements of WIM application. The pavement solution adopted is compatible with the WIM needs and guarantees durability for a long period of operation, keeping the requirements needed for direct enforcement. This solution was already tested and verified in previous research. Around the world there are WIM technologies that already have the international certification that meet the requirements of class 5E, according to the specification OIML-R-134-1-9.

The execution of the infrastructure for the pavement of the HS-WIM system bed considers the COST-323 recommendations for Weigh-in-Motion (WIM) sites, the French catalog of pavement structures, and the current Brazilian norms and legislation. For the design of the bed to the HS-WIM systems, a pavement structure was identified within the French catalog that would allow obtaining mechanical properties compatible with the technology application while resisting the forces applied by load vehicles during the design period exceeding 20 years (SETRA-LCPC, 1998). For the design of the ECP HS-WIM systems bed, the reference characteristics follow class I for geometry, deformation, irregularity, and longitudinal and transverse slopes.

During the execution control, the average deflection to be considered, measured on the pavement surface, should be less than 35 x 10^{-2} mm for an 8.2 t load and considering a material temperature of 25ºC. The control limit for execution is different from that established in COST, which was considered as the limit for design. Considering possible variations in material availability and local climate conditions, a tolerance value will be considered for class I.

Figure 7 – Thick Asphalt Concrete Pavement (TACP) for HS-WIM system

The pavement structure to be built is composed of multiple layers of Hot Mix Asphalt (HMA) with a total thickness of 46 cm, in addition to a pavement support layer made of lime-treated soil, with a modulus of approximately 120 MPa and a thickness of 100 cm. The asphalt layers consist of a layer of granular material treated with asphalt binder with a thickness of 30 cm, called in the French asphalt mix formulation, *Grave Bitume* class 3 (GB-3); an intermediate layer of high modulus mix with a thickness of 10 cm, called in the French mix formulation, *Enrobé à Module Élevé* class 1 (EME-1); and a wearing course layer of 6 cm, known in the French formulation as *Béton Bitumineux Mince* (BBM), as shown in Figure 7.

6 Conclusions

The PPM program is a temporary measure that DNIT plans to use until HS-WIM is legally permitted to perform direct enforcement. The program consists of the On-Road Control Station (ECP) and a Mobile Operations Unit (UMO), which are connected to an Operational Control Center (CCO) where a federal agent can take action against overloaded vehicles. DNIT has designed the PPM operation to meet international specifications such as COST 323 (2002) and OIML-R-134-1-9 (2006).

DNIT in Brazil has been a pioneer in implementing high-speed weigh-in-motion (HS-WIM) for direct enforcement of oversized and overloaded vehicles since 1980. In 2014, they launched the Integrated Automated Inspection Station model.

The PPM program follows international specifications such as COST 323 (2002) and OIML-R-134-1-9 (2006), and its operation must follow CONTRAN Resolution No. 902/2022. The technical solution includes automatic vehicle identification, pre-selection, vehicle classification, data traffic counting, dimensions and detection of excess height for vehicle classification, driver orientation, and information with Variable Messaging Sign (VMS), communication service, and control system integration of the different functionalities.

For the design of the bed for the HS-WIM systems, a pavement structure was identified within the French catalog, with a design period exceeding 20 years. A Thick Asphalt Concrete Pavement (TACP) was designed to meet the necessary requirements of WIM application. The execution of the infrastructure for the HS-WIM system bed pavement considers the COST-323 recommendations for Weigh-in-Motion (WIM) sites, the French catalog of pavement structures, and the current Brazilian norms and legislation.

It is expected that by mid-2024, WIM will be allowed to operate for direct enforcement. However, discussions are ongoing regarding the type of message to be communicated to the driver and the method of verifying that an overloaded vehicle has adjusted its weight.

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