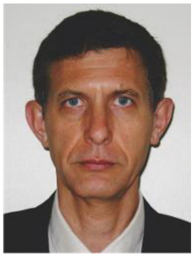
BRAZILIAN PIAF MODEL AND THE DIRECT ENFORCEMENT PROJECT

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Abstract
The paper presents the data used to design the model about Automated Integrated Weigh Station (PIAF) as well as three instrumented pavement technology for direct enforcement. The PIAF model includes a Control Station Runway (ECP), precision measurement runway and control of escape station that automated enforcement inspection in Operational Control Center (OCC). The pavement structures for performance evaluation in conjunction with the weighing equipment, specifically in ECP are sized in Continuously Reinforced Concrete Pavement (PCCA), Bituminous Pavement Modified by Polymer (PBEP) and Conventional Bituminous Pavement (PBEC).

Keywords: weigh in motion; WIM; direct enforcement; continuously reinforced concrete pavement; modified asphalt; weigh sensors, PIAF.

Resumo
O trabalho apresenta os elementos utilizados para concepção do modelo de Posto Integrado Automatizado de Fiscalização (PIAF), além de três tecnologias de pavimento instrumentados para fiscalização direta. O modelo PIAF contempla uma estação de controle em pista (ECP), medição de precisão e controle de fuga que, em conjunto, realizam a fiscalização automatizada através de um Centro de Controle Operacional (CCO). As estruturas de pavimento para avaliação de desempenho em conjunto com os equipamentos de pesagem, especificamente da ECP, são dimensionadas em pavimento de concreto rígido continuamente armado (PCCA), pavimento betuminoso espesso modificado com polímero (PBEP) e o pavimento betuminoso espesso convencional (PBEC).

Palavras-chaves: pesagem em movimento; WIM; fiscalização direta; pavimento rígido continuamente armado; ligante modificado; sensores de pesagem, PIAF.

1. Introduction

The Brazilian highways have been affected by the economic growing. The traffic volume of commercial vehicles operating on roads has increase due to the growth of the economy. Given this fact, the weight control is fundamental to preserve the structure of the road pavement, whereas in part there is the overloading of vehicles. The proposition of a new weigh station model and evaluation of different types of pavement are goals of cooperation agreement between the National Department of Transportation Infrastructure (DNIT) and the Federal University of Santa Catarina (UFSC) through the Laboratory of Transport and Logistics (LabTrans).

2. Brazilian PIAF Model

The definition of the Automated Integrated Weigh Station (PIAF) architecture aims to reduce human intervention as best as possible, as well as the execution of processes that involves the supervision of transit and transport in heavy vehicles. The PIAF must aggregate the latest operational and technological innovations and best practices to meet existing challenges in the best possible way. For this, the model has incorporated in its design the concept of pre-selection at the directive of the highway speed bearing, using as a basis the weighing technology on the move at high speed (HS-WIM: High Speed Weigh-In-Motion), Automatic Reading of Plates (LAP), and vehicle classification and recognition. Likewise, includes the performance of traffic officers from Operational Control Centers (OCC), enabling remote operation and in real time from one or more jobs simultaneously.

2.1 Automated Integrated Weigh Station (PIAF)

The Automated Integrated Weigh Station (PIAF) is an automated surveillance unit and modular, which allows performing a series of inspection procedures and data collection in the areas of traffic and security. This consists of three basic units, such as Control Station Runway (ECP – *Estação de Controle em Pista*), Escape Control Center (CFP – *Controle de Fuga em Pista*) and Inspection Station (PF – *Posto de Fiscalização*). Figure 1 shows the PIAF and presents the supervisory devices with its features.

The units that make up the PIAF have the function to carry out the supervision and control of the heavy vehicles that travel the highway. In this context, the ECP performs the pre-selection of all vehicles with any possible irregularity such as overweight or oversize. In the stretch of highway before the PIAF, the road signs should indicate to drivers about the area of supervision. In the case of highways with more than one line, lorries must, obligatorily, to keep in the right-hand lane before the ECP to the entrance of the checkpoint, in addition, the area around the ECP to the checkpoint must have segment with its controlled access.

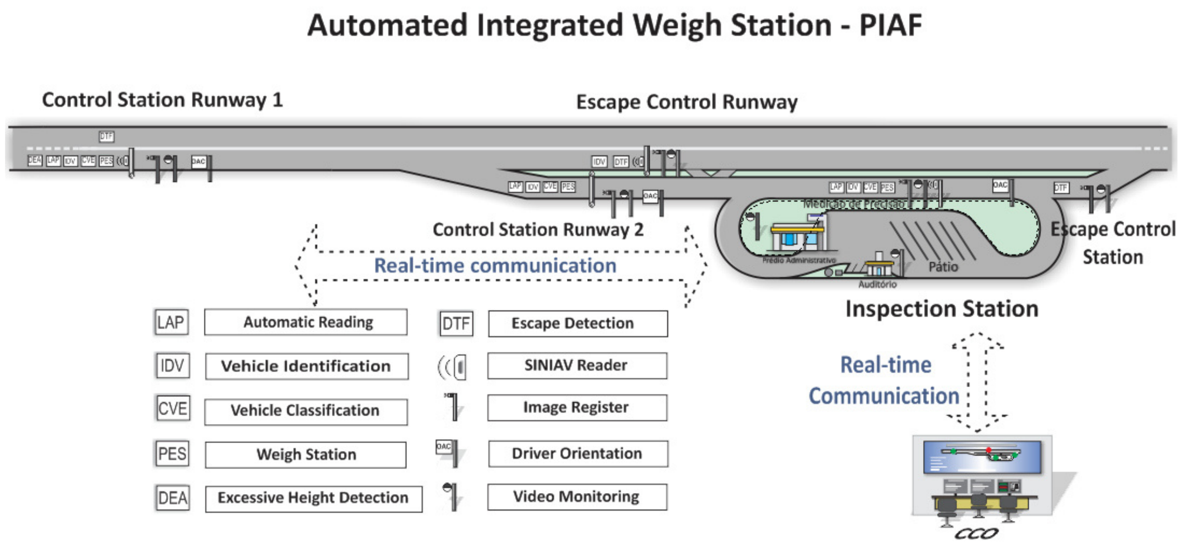

Figure 1 - Automated Integrated Weigh Station (PIAF)

The moment a vehicle passes by ECP, the WIM system collects all the information from covers identification as well. For any suspicion or irregularity detection, or for some reason the pre-selection is not be performed, the driver will be required to enter in the Weigh Station to be weighted in a precision scale. Calibrated equipment approved by the National Institute of Metrology, Technology and Quality (INMETRO). In addition to the measurements performed in the ECP, the pavement of the main lane is instrumented in order to carry out a data collection of the pavement behavior under vehicle influence. On this process, the pavement deflection response is collected at the moment the vehicle pass by.

A communication device, made with luminous signs, provide the driver the information to proceed to the weigh station (or not), just after ECP and before the weight station entrance, this can be done through variable message panels and/or semaphores. Vehicles which go through the road shoulders, between lanes or by the right lane (not indicated for heavy vehicles), should be properly identified. The main identification are ANPR software and photo. All containing the time of the infraction define by a specific legislation. The same procedure is performed when a vehicle bypass the Weigh Station in attempt to avoid the precision scale measurements. Finally, any attempt of escaping from enforcement the vehicle must be identified by the surveillance system on the station.

At the PF, the vehicles shall be subjected to precision scale inspection and all procedures are monitored by the OCC.

2.2 Ntional road distribution of PIAF

The location of PIAF must be validated accordingly with its functionalities, considering the effectiveness and feasibility of installation. The first step was a verification and analysis of the possible sites to installation. A pre-analysis of the pre-appointed locations, uses a geoprocessing system (ArcGIS) for visual and graphical analysis. To phases are needed to weigh station location analysis. The first phase assessed the existent vehicle Weigh Stations (PPV) uses by DNIT for mobile and fixed enforcement on the federal highway network. In the second phase, the new fix and mobile weigh stations, constant in the public notice 11-

0162/00 called PIAF, which should be evaluated and analyzed. For each of these phases, two main criteria for choice of PIAFs were created, considering both effectiveness and feasibility.

The General Road Operations Coordinator (CGPERT) of the DNIT defines the selection criteria to define when and where to construct the PIAFs. In 1st and 2nd phases, there are two main criteria: 1st criteria: will not be considered in analyzing the a PPV located on highways currently granted and with granting future defined by the Federal Government. 2nd criteria: will not be considered in analyzing the PIAFs located on highways where the total heavyweight vehicles are less than 500 trucks/day. For inclusion or exclusion of any PIAF, both criteria are take into consideration.

A GIS program is than feed with the locations of the pre-selected sites. The information is divided between the two phases of analysis. The data from each location and the information from the govern database are divided using layers. The layers are separated between phases. 1st Phase (existing PPV) and 2nd phase (new PIAF). Types of weighing station (fixed or mobile). Quantity of heavy trucks. Highways Concessions or not. Location and amount from productive sectors in Brazil (sugar, ethanol, copper, nickel, Tin, fuels, pig iron, wood, corn, iron ore, paper, cardboard, steel products and soy). Fiber optic communication. In addition, existence of possible escape routes.

With the individual or collective selection of these different layers, it was possible to generate maps for review and decision on the PIAFs. All maps contain the title of the corresponding layer, the compass, the scale used and the caption of the lines and the points contained in the map. The data about the current conceded highways and future concessions have been provided by the National Agency of Terrestrial Transports (ANTT). Figure 2 present a map locating all stations from 1st and 2nd phases (fixed and mobile), in conjunction with the highways marked with the greatest volumes of heavyweight vehicles.

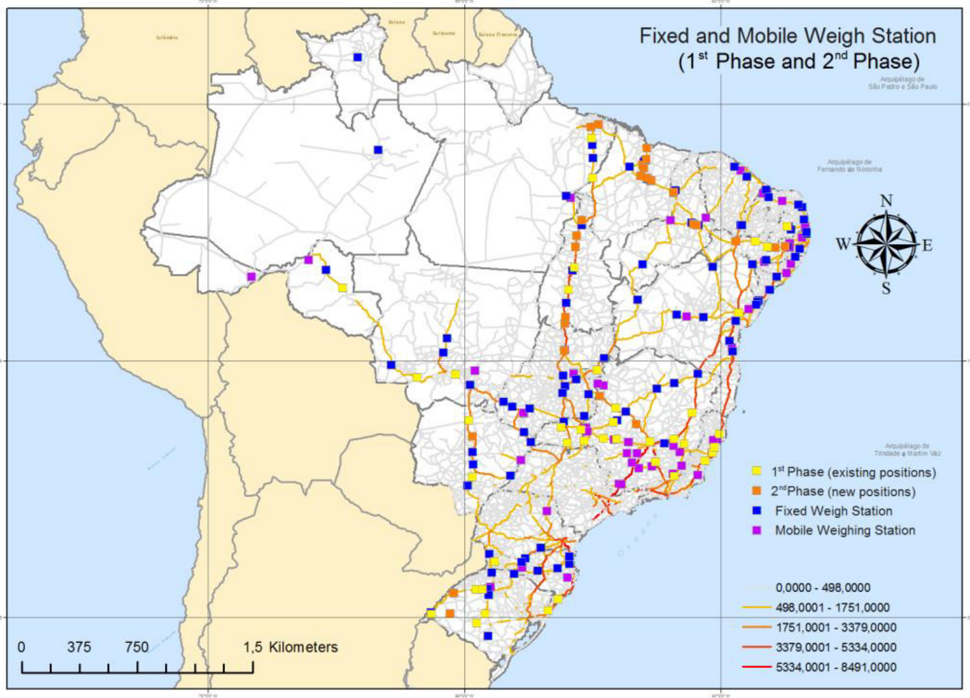

Figure 2 - Fixed and mobile PPVs (phases 1 and 2) with the volume of heavy trucks

Most of the stations located along the highways with the greatest volumes of heavy trucks, which travel on exporting or importing products. The PIAF locations are concentrated in the South, Southeast, Midwest and Northeast of Brazil. Grouping the PIAFs around regions, such the points in the map, there are areas in the North of the country with the lower concertation of PIAF stations, mainly because the volume of heavy vehicles on that road is less than 500 trucks per day. There are a large number of vehicles coming to deliver in the ports than coming from it. That is way most of the PAIF are located near the coast and less in the countryside.

2.3.Projects of Automated Integrated Weigh Station(PIAF)

The PIAF design project establishes the premise of infrastructure adopted should ensures durability during the life cycle and ensures continuously effectiveness and performance features. The design took into account to the recommendation stablish at specifics standards, manuals, instructions, and quality control. The geometry of the road around the ECP must meet the criteria defined as Class I at the COST 323 (1999), which defines the sit as excellent for WIM systems.

The pavement structure chosen for the ECP is a continuously reinforced concrete pavement as recommended in the method and orientation of the Continuously Reinforced Concrete Pavement manual from FHWA (2009). The parking lot area is design using an Interlocking Concrete Paver, working as a more ecologic solution. The acceleration and deceleration lanes and precision measurement are both design using a concrete pavement slab with dowel bars and rebar mesh. The experience gained during the years of operation of weigh stations showed how susceptible are those sections of pavement to the effect of acceleration and deceleration of vehicles.

The accommodation of vehicles in the courtyard and the access handles that give passage to the parking courtyard will be scaled so that the Loading Vehicles Combinations (CVCs) does not have accessibility problems. The legislation governing the requirements necessary for the movement of CVCs is resolution No. 68 of 9/23/1998, of the National Transit Council (CONTRAN). This legislation stipulates that the CVC can't introduce total gross weight exceeding 74 tons and its length must not exceed 30 meters. For the study in question the inter-links of articulated seven axes (BT7), road-train of nine axles (BT9), “Romeo and Juliet” of seven axes (BTL), multiple trailer of seven axes (CA) and the truck Stork (CG), were considered.

The precision scales and the concrete slab design at the influence area of the scale are between the responsibilities of the contracted party. In this way, materials specifications, design, execution and maintenance will depend on the type of equipment selected to operate at the PF.

The administration building at the PIAF shall meet the requirements of law No. 10098, of 19 December 2000, and the NBR 9050:2004, which defines accessibility to Buildings, furniture, urban equipment and Spaces as regards technical parameters to be observed for the assistance to persons with disabilities or reduced mobility. The criteria for the access ramps must agree with recommended as well as doors openings and circulation areas throughout the entire building.

3. Direct Enforcement Project

To achieve success in projects of direct supervision is necessary for the performance of the components required for this purpose is in constant consonance and the knowledge and use of new technologies assist in this process. The equipment of weighing sensors need to be installed on specific pavements, that meet the proper standards for correct functioning, and in the same way all the WIM equipment should collect data properly.

The project COST 323 (1999) has defines standards and specification for WIM systems using either pavements or bridge structures. In relation to the type of pavement, the COST defines features for identify structural characteristics divided by classes. The minimum required class for direct enforcement using WIM systems for high speed is Class-I, see characteristics in Table 1.

Table 1 - Parameters for installation of WIM systems Class I (COST 323, 1999)

PARAMETERS FOR INSTALLATION OF WIM SYSTEMS - CLASS I	
Maximum longitudinal slope	≤ 1%
Maximum cross slope	≤ 2%
Radius of curvature (more possible tangent)	~ ∞ m
Permanent deformation (3 m beam)	≤ 4 mm
Pavement deflection (Benkelman beam 13t)	≤ 20 (10-2) mm
Pavement deflection (FWD 5t)	≤ 15 (10-2) mm
Roughness by index IRI (m/km)	≤ 1.3

3.1 The pavement structures

In order to search for new solutions of road pavement structures that meet the conditions of the weighing system in motion for direct supervision, it is performed a proposal of three solutions of instrumented floors. These decks are designed to follow the assumptions and concepts defined for the new model of post quoted in item 1.1 getting thus technological knowledge to present alternatives aimed at improvements in the management of the infrastructure of the weigh stations under jurisdiction of the DNIT.

The experience acquired in 2008, were installed 64 weighing sensors (quartz, ceramic, polymer and optical) on a station built with standard floor and allowed to infer that the floor used in Brazil did not submit necessary features to meet the requirements of WIM systems. It was proposed three new solutions: Continuously Reinforced Concrete Pavement (PCCA); Bituminous Pavement Modified by Polymer (PBEP); and Conventional Bituminous Pavement (PBEC).

2.2.1 Continuously Reinforced Concrete Pavement - CRCP

The Continuously Reinforced Concrete Pavement (CRCP – in Brazil called "*Pavimento de Concreto Continuamente Armado*" – PCCA) respects the guidelines for design and construction of the Federal Highway Administration manual: Continuously Reinforced Concrete Pavement Design & Construction Guidelines (FHWA, 2009). This type of pavement allows the continuation of load transfer, without cross-joints due to the continuous longitudinal steel. The structure of the profile for the PCCA is shown in Figure 3.

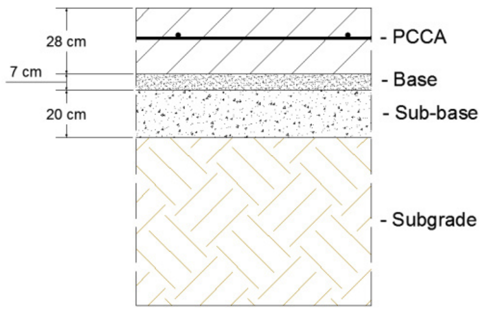

Figure 3 - Continuously Reinforced Concrete Pavement

The amount of longitudinal steel was determined in steel bars 25 CA-50 (25 mm) spaced at 23 cm and 135 cross armor steel bars CA-50 (16 mm) spaced at 100 cm.

2.3.2 Bituminous Pavement Modified by Polymer - PBEP

The sizing of Bituminous Pavement Modified by Polymer (PBEP) is performed through the methodology of French catalog, along with the definitions imposed by COST 323 (1999) a floor suitable for the WIM system. The catalogues are based on empirical and mechanistic analyses that use the highway performance built to interpolate and extrapolate the prediction of the behavior of new projects. The principle of the mechanistic basis of catalog is the assessment by means of a mechanical model compared with the results of the characterization laboratory material (mainly with regard to fatigue resistance and stiffness). In this model, the features of the behavior of materials and traffic and, as a result, are evaluated levels of deformations and stresses subjected to this structure. In short, the method looks for the best combination of technical solutions (type of structure, materials) and project requirements (strategy, traffic, and climate).

The COST 323 (1999) specification defines that, for class I of WIM system, the maximum deflection should not exceed 20x10-2 mm, as shown in table 1. Using computational methods of scaling (for example, Viscoroute) for the maximum deflection, a platform must have a minimum strength of 120 Mpa. For this reason, it was necessary to use a reinforced layer of soil-lime in the base. Given this, the features for the PBEP include structural pathways ("*Voies du Réseau Structurant*" - VRS); record class 3 asphalt (GB-3); class 3 support platform (PF3) and; heavy vehicle fleet of 30 million tickets equivalent axle (TC7). With these characteristics, the catalog of sizing indicates a structure with a surface layer "Couche of Surfing" (CS) based on three layers of treated bases (GB). So, it was defined a structure with 6 cm of bearing layer added to the 10 cm layer of high module (minimum set by COST 323 to the link layer) and a total of 31 cm treated base layer (10 + 10 + 11 cm), as shown in Figure 4.

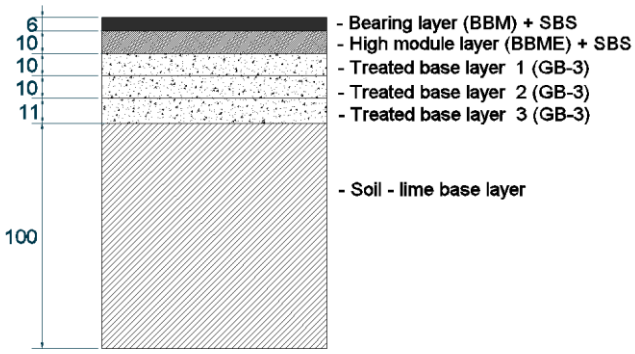

Figure 4 - Bituminous Pavement Modified by Polymer

The binder set is the CAP 30/45 modified with polymer SBS (Styrene-Butadiene-Styrene) and the percentage of asphaltic concrete layers ligand GB is based on manual table of design of bituminous mixtures of LPC (2007) specified in at least 4.2%. Already the other layers the binder is content of 5.5%.

2.3.2 Conventional Bituminous Pavement - PBEC

For the sizing of Conventional Bituminous Pavement used the results of laboratory tests to define the French particle size, thickness of concrete and asphalt binder content of researches of high module (Module Enrobé Élevé - EME) of Quintero (2011) and the base mixture treated (Grave-Bitume - GB) Almeida (2013). The parameters used for the dimensioning of this section considered traffic class TC6 (heavy) with 5.000 vehicles/day; coefficient of 1.0 aggressiveness; standard shaft 130 kN; annual growth rate of 3.5%; project period 10 years; risk coefficient 10% and Poisson coefficient 0,35. Defined, so the floor thicknesses with 6 cm layer of bearing with 5,5% of CAP 30/45; 12 cm thick asphalt mixture with 5,5% of CAP 30/45; 24 cm of gravel base graduated with 4,2% of asphalt binder; 30 cm of sub-base of gravel graduated and the last metro of the sub-ground treated with 5% of cal.

3.2 The location

The construction site of the experimental station with WIM sensors for direct supervision is in the city Araranguá, located in Santa Catarina, a state situated in southern Brazil, specifically on highway BR-101 km 416. Figure 5 illustrates the location of the three types of pavement (section I PBEC, section II PCCA and section III PBEP), next to the Vehicle Weigh Stations (PPV) the DNIT.

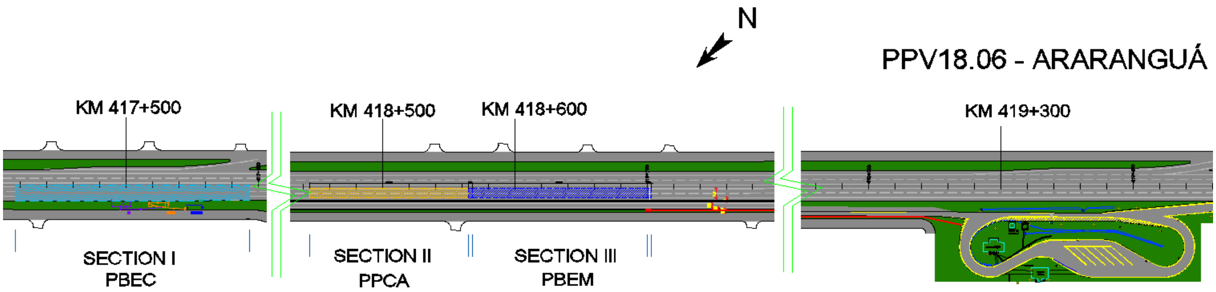

Figure 5 - Location of the three types of pavement in the experimental station

Each floor technology has the extension of 120 m, 70 m and the 20 m finals reserved for the area of influence of the sensors, while the central 30 m are reserved for the installation of weighing sensors and deflection sensors. In addition, between the 2nd and 3rd section are reserved 15 m for transition slab in order to avoid problems with the thermal dilation and discomfort.

3.3 The instrumentation

The development for improvement of weighing in motion with a focus on direct supervision converges to the good performance equipment, deck and operation. In this line, the experiment with WIM systems is to reproduce the basic functionality required in the project whose function is the control of heavy vehicles directly on the highway at speed directive, as shown in Figure 6.

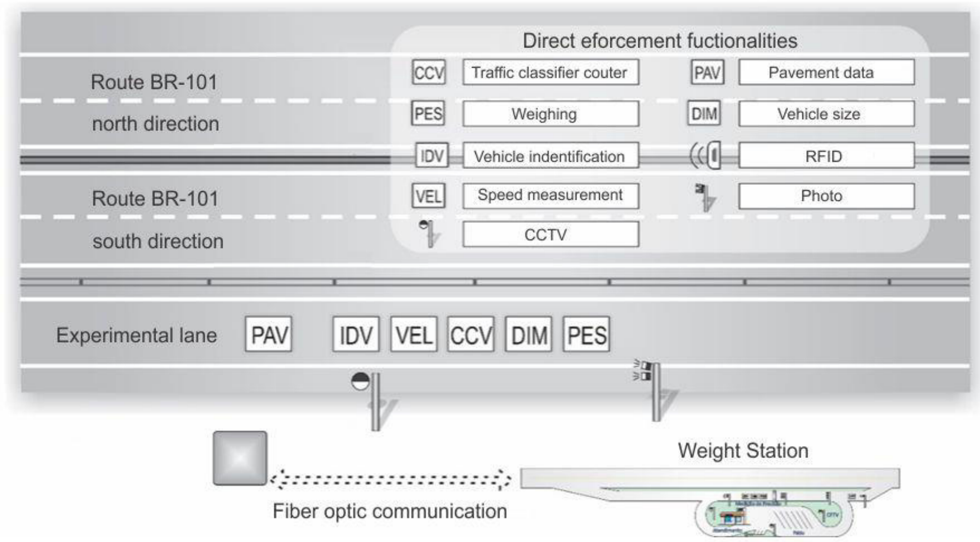

Figure 6 - Features for direct supervision systems WIM

The model, which encompasses the instrumentation of weighing sensors with peripheral equipment for surveillance, as illustrated in Figure 7.

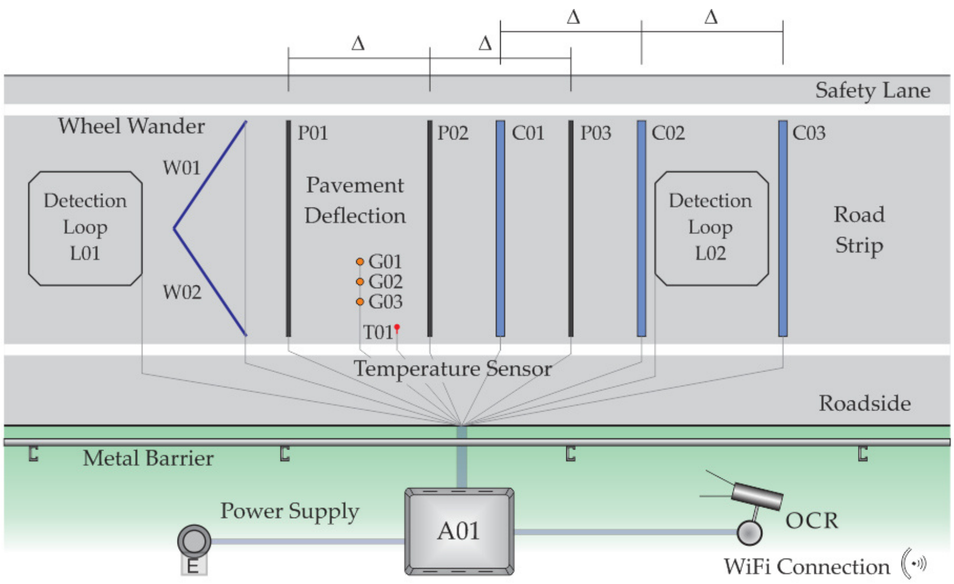

Figure 7 – Equipment installation for direct supervision

The W represents the polymer sensor in order to detect the position and identification of shot; P polymer sensor for weighing; the sensor C ceramic; T temperature sensor; L detection loops; and G the Geophones. In addition to these items, you will find the data acquisition system and camera OCR.

3.4 Conclusion

Currently, 35 Automated Integrated Enforcement Weigh Stations (PIAF) are already tendered and contracted with forecast for operation in 2017. The next step is to cover 27 more posts in this new format of checkpoint across the country. In relation to three types of floors to direct surveillance instrumented, the section it was built in 2013 by starting the new process of assessing the performance of the weighing systems moving at high speed, using as reference data collected at Vehicle Weigh Stations (PPV), provided by DNIT. The model of operation follows the standards previously developed solutions for companies, both in terms of how sensors in terms of integration. Currently, these solutions are under evaluation, adaptation and improvement front conditions and peculiarities, which were found during the operation. In addition to these facilities, the experimental station in Araranguá has an OCC, along the lines of PIAF, in which simplified way reproduces the operation from a distance in order to assess the demand of transmitted information and test the integration of different technologies installed on the station with their pavement technologies.

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