

## ABSTRACT

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**Title:** Utilisation of Weigh-In-Motion in South America for the Protection of the Highway Infrastructure

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### **Abstract:**

This paper discusses the use of Weigh-In-Motion (WIM) Systems to protect the highway infrastructure. Overweight trucks cause an exponential increase in the acceleration of road wear. Weigh-In-Motion Systems are used to minimise costly damage and deterioration of the highway infrastructure. WIM Systems located at or near Truck Inspection Stations use in-road scales, which weigh trucks in motion to determine if they are within weight compliance and dimension regulations. Those trucks which are identified as overweight are directed to a Slow Speed WIM Scale for further weighing and inspection by enforcement officers. A penalty ticket is issued to operators of trucks which are overloaded. Those trucks which are identified by the WIM System as being within compliance regulations do not have to stop for further weighing, and can use a bypass road to continue to the main highway.

Specifically, this paper will discuss the WIM System operations in Brazil. The President Dutra Highway connects two of the largest urban areas in the world. The Dutra between São Paulo (population of 17-18 million) and Rio de Janeiro (population of 13 million) is one of the main highways in South America to utilise Weigh-In-Motion. The Dutra is a toll highway and is one of the busiest highways in South America, with an average of 180,000 vehicles per day, 50% which are trucks. Almost 45% of Brazil's Gross Domestic Product (GDP) of \$900B USD is accounted for by the trucks that travel this highway. The WIM Systems at the Truck Inspection Stations on this highway are comprised of Medium Speed Sorting Scales and Slow Speed WIM Enforcement Scales and use one of the most advanced operating systems in the world.

WIM systems provide economic benefits to highway operators, trucking companies and the general public. Through the use of Weigh-In-Motion, Brazil benefits through better protection of the highway infrastructure, improved productivity and efficiency, and enhanced safety.

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**UTILISATION OF WEIGH-IN-MOTION IN SOUTH AMERICA FOR THE  
PROTECTION OF THE HIGHWAY INFRASTRUCTURE**

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## Introduction

A nation's transportation infrastructure is its economic lifeline. An efficient and safe road network allows goods to reach the markets quickly to stimulate economic activity and to ensure trade competitiveness. More efficient travel allows motorists greater ease of travel, less frustration, and increased mobility ~~and more time to spend at other activities~~. A healthy transportation infrastructure is vital for any nation's economic and social well being. Today, the need for ~~weight control and~~ efficient highway management is becoming increasingly important to protect and maintain the quality of road infrastructure ~~around the world~~. While many technologies exist to enhance various aspects of transportation systems and related activities, ~~only weighing~~ ***is a critical factor in addresses the issue of road preservation***. For nearly twenty years, Weigh-In-Motion (WIM) systems have been used to complement static weighing and other weight enforcement operations. WIM is a valuable and proven tool for road preservation, in two primary applications:

1. Enforcement prescreening ~~to will help to~~ prevent premature deterioration of the highway and bridge infrastructure, and
2. Collecting traffic data for infrastructure design, maintenance schedules, highway management, overload detection, and evaluation of pavement performance.

Brazil has recently initiated a WIM program on the President Dutra highway. The system in Brazil is an excellent example of the use of WIM for weight enforcement and data collection.

## Weight Enforcement

Controlling truck weights through weight regulations and effective enforcement is critical to preserve the life of a road and to minimise pavement costs. Pavement cost is more dependent on the level of enforcement than weight limit. Increased loads mean shorter pavement life and more frequent maintenance and rehabilitative work, which add to the cost of a highway and the cost to taxpayers. Thus, ~~strict weight monitoring enforcement and enforcement~~ can result in minimised pavement costs and savings to taxpayers. An increase in loading results in a fourth power exponential increase in the acceleration of road wear. In other words, if a pavement is subjected to 10% overloading, it can mean an acceleration of road wear by over 45%. Ultimately, weight regulations are intended to balance the economic benefits of commercial vehicle operations with the various costs resulting from large trucks, including road wear, increased maintenance, new construction, risks to public safety and additional design requirements for the infrastructure. Weight enforcement ensures that weight regulations are obeyed.

In many countries, weigh stations equipped with static scales are used to enforce weight regulations. Static scales are highly accurate and are excellent for weight enforcement purposes, so long as the truck traffic does not exceed the capacity of the scale facility. At busier weigh stations, when the rate of trucks enter the station faster than the rate at which trucks can be weighed statically, many problems can arise. Traffic can back up onto the highway causing safety hazards, drivers may be subjected to lengthy and unnecessary delays from long queues, and weigh stations may be forced to close temporarily to allow its operators to finish weighing the trucks already in the queue. When weigh stations close, some trucks are able to bypass the weighing process, even though they may be overweight without a permit.

Weigh in Motion (WIM) technology is an efficient and cost effective solution to complement static weighing, minimising unnecessary stops and delays for truckers. WIM scales

dynamically weigh trucks travelling at high speeds, to provide preweighing, prescreening and presorting at weigh stations. When WIM systems are installed on the mainline, *all* trucks are weighed. The WIM system sorts all vehicles based on preclearance criteria determined by the enforcement agency, such as weight and credentials. The WIM system directs only vehicles suspected of non-compliance to report for further inspection. Those suspected of overweight or oversize violations are directed to report to the static scale lane, while all others are allowed to bypass with minimal interruption. A ramp sorter station requires medium speed WIM scales to be installed on the entrance ramp to a weigh station. All trucks are required to enter the ramp where they are weighed at medium speeds. Only those found likely in excess of the legal weight limit must proceed to the static scale for further weighing. All others are given a bypass message and are permitted to return to the mainline without delay. The weigh stations on the President Dutra Highway are a ramp configuration. The reduction of trucks required to report to weigh stations has additional benefits including: safety, from fewer truck exits to and merges from the weigh station; lower operating costs, from less wear and tear on the static scales; more focused and thorough inspections, from lower traffic volumes reporting to the weigh station; and, fewer overloads from greater enforcement visibility and effectiveness.

WIM is a valuable enforcement tool for many reasons. WIM targets potential violators and eliminates unnecessary delays for legal operators. WIM frees up enforcement resources to concentrate on unsafe and non-compliant carriers and trucks. WIM retrofits to existing weigh stations and makes them more efficient, without costly renovations or new construction. WIM encourages clean safety records and compliance with regulations by targeting potential violators for further inspection. WIM systems help to level the playing field between illegally operating carriers and carriers who operate in compliance with the law. More importantly, WIM systems help to minimise the likelihood of illegally overloaded trucks travelling on the nation's highways, reducing the rate of road deterioration.

### **Data Collection**

In addition to being a tool for weight enforcement, WIM systems perform another valuable function - WIM systems continuously collect data on truck weights, speeds, time of travel, axle configurations, and volumes. WIM systems can be used to collect valuable traffic data at all times, even when regular truck weigh stations are not operating. This is especially important because the number of overweight trucks drops sharply when weigh stations are known to be in operation. The data collected by WIM systems have proven to be invaluable for planning and enforcement purposes. For example, in the United States, California and New Jersey implemented state wide WIM data collection systems to collect traffic data, such as volume, speed, classification, weights, configurations, etc. for the purposes of predicting traffic patterns and loading requirements in order to design their pavements accordingly. For other states and agencies, use of WIM data has helped better plan maintenance activities and future upgrades based on loading patterns. Without WIM systems in place, it is nearly impossible to predict the nature, frequency or even cost of overloading. The Seaway International Bridge Corporation (SIBC), responsible for the management of the Seaway International Bridge between New York state and the province of Ontario implemented WIM systems in 1996. Based on the data collected, SIBC has identified a weight overload problem and is now able to address the situation based on known data. Other states, such as Idaho, have used their WIM systems to identify overloading problems when the weigh station was closed. Consequently, they were able to justify additional enforcement hours during the night, based on the WIM data.

Having access to reliable traffic loading data helps highway departments to correctly plan maintenance activities and rehabilitative measures to ensure the prolonged integrity of a road. When maintenance activities are mistimed due to inaccurate traffic loading estimates

or overloading, it can result in the degradation of a road. WIM systems provide the state enforcement agencies with valuable traffic information data, which is owned by the agency and can be used by the agency for management, evaluation and planning purposes.

WIM data can also be used to evaluate the performance of pavements. Implementing WIM systems to collect data helps transportation analysts to determine the performance of the pavement mixtures. For instance, when a road is built, it may be designed for specific loading, environmental and life cycle parameters. In order to evaluate whether the design was adequate, it is necessary to know what the actual loading conditions were. Two pavement designs may have a similar life cycle, but one may have been subjected to much harsher loading conditions. Knowing the actual loading conditions provides a better comparison between the actual performance of the pavements. Does one road last longer because of superior performance or because of less than expected loading? WIM data provides accurate and unbiased loading data necessary for analysis.

### **Economic Benefits**

WIM systems provide economic benefits in many respects. From an enforcement perspective, WIM systems target overweight vehicles for further inspection. This reduces the number of illegal overloads on the roads, which reduces pavement damage and lowers pavement costs. WIM also helps enforcement operations become more efficient through focused attention on the problem trucks, freeing up enforcement resources and facilities for their intended use. Reduced delays for legal carriers could mean significant savings to the trucking industry and their consumers.

From a data collection perspective, WIM systems provide invaluable traffic data for better planning and management of maintenance and new construction activities. Accurate loading data provides highway officials with the opportunity to adjust their maintenance and rehabilitation schedules based on actual levels of deterioration. For example, rehabilitative maintenance may be performed two years earlier than scheduled or more frequently if the traffic volumes exceed the design volumes. This ensures that rehabilitative maintenance is timed correctly, rather than after the structural integrity of the road has already been breached. Since maintaining a good road is five times less expensive than rehabilitating a poor one, it is important to prevent roads from deteriorating. Furthermore, since rehabilitating a bad road is much less expensive than new construction, it is very important to avoid reconstruction and new construction wherever possible. WIM systems also allow transportation officials to plan new construction based on actual pavement loading. Using WIM data, much of the guesswork involved with estimating traffic conditions is eliminated, allowing for more suitable designs. Thus, pavement designs are not under designed, nor over designed, both of which are costly situations to remedy.

### **Primary Objectives of Automated Truck Weigh Stations**

The benefits of automated truck weigh stations are bestowed primarily upon the following groups:

1. The general public
2. The trucking industry
3. The infrastructure operating authority

The use of WIM stimulates the economy through the more efficient movement of goods. An example of the impact of trucking on a local economy is the President Dutra toll highway in Brazil. It is one of the busiest highways in South America, with an average of 180,000 vehicles per day, 50% of which are trucks. Almost 45% of Brazil's Gross Domestic Product

(GDP) of \$900B USD is accounted for by the trucks which travel this highway. By improving the movement of these trucks in an efficient and safe manner, Brazil's economy and public well being are improved.

Another significant benefit is more efficient use of toll or tax dollars. Overweight trucks cause exponentially greater damage to the infrastructure than trucks that are loaded within the legal limit. The cost to repair or replace pavements that fail due to overweight vehicles is extremely high. It is estimated that a 10% increase in the ESALs (Equivalent Single Axle Loads – 80kN) on US highways would increase pavement damage costs by \$375 million per year. Preventing the overweight vehicles from travelling and damaging the road network extends the lifespan of the infrastructure and results in a direct savings to taxpayers.

Automated truck weigh stations improve public health and safety. The use of automated truck weigh stations reduces the number of entrances and exits of heavy vehicles onto the roadway. Minimising merging activities and allowing vehicles to travel at consistent speeds result in increased safety for all highway users. When trucks are permitted to bypass the weigh station a reduction in fuel emissions is experienced, as a result of reduced idling time. This in turn provides a healthier environment and a healthier population.

The trucking industry receives direct financial benefit from the use of automated truck weigh stations. When a truck is permitted to bypass a weigh station, the saving is in time. Unnecessary delays at weigh stations result in significant cost to the trucking industry. Additionally, faster deliveries and reduced fuel consumption provide increased profit for the trucking industry. WIM gives the benefit of the doubt to regularly compliant operators, by allowing vehicles that are within legal weight limits and displaying compliant credentials the opportunity to bypass the weigh station.

The highway operating authority receives significant benefit from automated weigh stations. The primary benefits are the preservation of the highway infrastructure and increased revenue generation. The use of WIM allows the operating authority to prolong the life of the infrastructure. On busy highways using traditional weighing methods, it is not uncommon for a weigh station to become too busy to accept any more vehicles, hence the station must be closed for a period of time to allow the operators to catch up on the backlog of vehicles. During this time, all other trucks are permitted to bypass. With the use of automated truck weigh stations, fewer compliant vehicles are required to stop, allowing the enforcement officials to focus their efforts on those vehicles that are likely to be non-compliant. The use of WIM extends the life of existing enforcement facilities by expanding their capacity.

### **Weigh-in-Motion in Brazil**

The President Dutra Highway in Brazil is a toll highway that is travelled by a large percentage of trucks. In an effort to protect the infrastructure, the concessionaire, Nova Dutra, in conjunction with International Road Dynamics Inc. (IRD) has implemented a system of sophisticated automated truck weigh stations. One of the stations has been installed, commissioned and accepted at Queluz, located approximately midway between Rio de Janeiro and Sao Paulo. The Slow Speed Weigh-in-Motion (SSWIM) system for enforcement weighing has received INMETRO approval for weighing trucks, including those carrying liquid loads. The system installed at Queluz has received IPM approval.

The system consists of medium speed Single Load Cell scales for truck overload sorting and SSWIM scales for enforcement weighing. The configuration is a ramp sorting system, followed by enforcement weighing using SSWIM scales for vehicles that are found to be near the weight limit by the sorter system. As a truck approaches the weigh station a sign requiring all trucks to report is viewed. The driver enters the ramp where the truck is

automatically weighed and classified by the Single Load Cell WIM. A vehicle record is created containing the information from the medium speed scale. The data from the vehicle record is used to determine whether the vehicle is within legal weight limits. Following medium speed weighing, the truck movement is controlled by directional signals. Vehicles that are determined compliant by the WIM system are given a signal instructing them to return to the highway without further delay. Vehicles that are indicated as overweight by the medium speed WIM system are directed to the SSWIM for enforcement weighing. The vehicles travel over the SSWIM scale at a speed between 2-10 km/h and the individual axle weights are calculated. If the vehicle is overweight, the SSWIM computer will automatically set the sign system to direct the vehicle to the parking lot for citation processing. If the vehicle is within the legal weight limits, the SSWIM computer will automatically set the signs to direct the driver to leave the weigh station.

The Nova Dutra Weigh Stations include a video system, a mainline tracking system and a parking lot occupancy tracking system to enhance the operation of the system. The video system records an image of all vehicles that report to the SSWIM scales for enforcement weighing. The image is included in the vehicle record. The mainline tracking system follows the movement of all vehicles that do not enter the weigh station ramp. A piezoelectric WIM system on the mainline is used to determine the weight of the vehicles that bypass the station. This alerts the station operators to the presence of trucks that try to avoid the weigh station and provides continuous traffic data, even when the station is closed. Tracking loops are also included throughout the ramp area to follow the movement of vehicles through the weighing process. A system of loops at the entrances and exits of the parking area monitor occupancy and permit the vehicle flow to remain constant between the parking area, the SSWIM scales and the exit to the main highway.

Central Administration Computers (CAC) are designed to link all of the weigh stations to a single database. This allows the processing of data from all of the stations at a single location. Additionally, the CAC computers enable the administrators to access data from any of the stations in real time.

The use of WIM in Brazil encourages drivers to operate within the legal weight limits. Drivers that are not compliant and are causing greater damage to the highway are likely to be detected through the use of WIM for enforcement. This results in illegal operators receiving fines and reduced profitability, while compliant operators receive the benefit of fewer delays.

WIM is an essential component of the pavement management efforts on the President Dutra Highway. Through the use of WIM, a combination of enhanced enforcement and increased traffic data collection is achieved. This provides the information needed for a well managed infrastructure resulting in lower life cycle costs and improved ease of travel for both the trucking industry and the general public. The benefits of WIM in Brazil and in many other parts of the world are multi-fold.

## **Conclusion**

In recent years, the use of WIM technology as an enforcement and management tool has been increasing steadily. The role of WIM in road preservation has two main applications: weight enforcement to minimise the deterioration of roads, and data collection for management and planning purposes. Brazil has recently adopted a program of WIM for enforcement and data collection through the use of sophisticated automated truck weigh stations on the President Dutra Highway. The first station is installed and performing to the satisfaction of the Nova Dutra concession.

**Keywords:**

ITS, Brazil, South America, Data Acquisition, Detection, Deterioration, Freight, Maintenance, Pavement, Weigh-in-Motion

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