PERSPECTIVES ON THE USE WEIGH-IN-MOTION (WIM) FOR ROAD SAFETY APPLICATIONS IN NORTH AMERICA

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Abstract

This paper provides a review of how Weigh-in-Motion (WIM) systems have been used for road safety in North America. This includes applications where overload control is the direct means for promoting road safety and WIM systems that are integrated with other ITS devices to create comprehensive automatic inspection sites that are used as screening tools for road safety inspections. This paper aims to provide insight to road owners, public agencies, and road safety specialists about how to effectively deploy WIM systems in conjunction with other ITS devices to promote safer roadways.

Keywords: Weigh-in-Motion, WIM, HS-WIM, Reliability, Safety, United States, Canada.

Resumen:

Este artículo proporciona una revisión de cómo los sistemas de pesaje en movimiento (WIM) se han utilizado para la seguridad vial en América del Norte. Esto incluye aplicaciones donde el control de sobrecarga es el medio directo para promover la seguridad vial y sistemas WIM que se integran con otros dispositivos ITS para crear sitios de inspección automática integrales que se utilizan como herramientas de detección para inspecciones de seguridad vial. El objetivo de este artículo es proporcionar información a los propietarios de carreteras, las agencias públicas y los especialistas en seguridad vial sobre cómo desplegar eficazmente los sistemas WIM en conjunto con otros dispositivos ITS para promover carreteras más seguras.

Palabras clave: Weigh-in-Motion, WIM, HS-WIM, Confiabilidad, Seguridad, Estados Unidos, Canadá.

1. Introduction

Vehicle overloading may have a significant impact over the risk of accidents, and these accidents can become more severe when it involves an overloaded heavy vehicle. In North America, because of the association between vehicle overloading and vehicle safety, many road enforcement organizations have adopted strategies where vehicle overload and other safety attributes are inspected at the same physical locations and enforcement personnel.

It is generally known that vehicle overloading has implications on road safety. Although it is difficult to draw direct relationships while isolating all other variables in tests involving a roadway setting, some studies have demonstrated this relationship through mechanical analyses and common sense. Research indicates that vehicle overloading increases risks in accidents involving rollover, break failure, locked wheels, and tire failures (Ervin et al., 1983; Harwood et al., 2003; Moreno et al.; 2018).

Several other hypotheses have been discussed for why vehicle overloads may contribute to the number and severity of road crashes. Most of the existing evidence and hypothesis are discussed in detail in work of Turner and Nicholson (2009).

The use of WIM in road safety applications in North America has evolved over the years and it is still changing toward more automation and more information being collected at the enforcement sites. The combination of enforcement actions has become beneficial because it promotes safer roadways through more comprehensive inspections, and it saves resources by having inspections sites that serve multiple purposes.

Now, WIM for road safety in North America is reaching a point where the weight information may be used as a direct means for making informed decisions about enforcing safety standards. This happens because tire loading can be a critical aspect in vehicle safety.

The content in this paper may inspire professionals who wish to promote safer roadways through the combined use of high-end WIM systems and other complementary inspection technologies. The paper will demonstrate how an automated enforcement system that uses high-end WIM and tire inspection technologies ultimately serves to protect the public from accidents involving poorly maintained and overloaded vehicles.

2. Virtual Weigh Stations (VWS)

Virtual Weigh Station (VWS) is the name given in North America for high-performance WIM sites installed on the mainline for enforcement screening (also referred to as pre-selection). These WIM sites are often integrated with Automatic License Plate Readers (ALPR) or other automatic vehicle identification devices. VWS gained wide use in North America in the 2000s, with their implementation across different states being supported at the federal level. The use of these WIM stations opened the possibility of expanding the scope and efficiency of weight enforcement programs, particularly by targeting enforcement resources where non-compliance is more likely to occur.

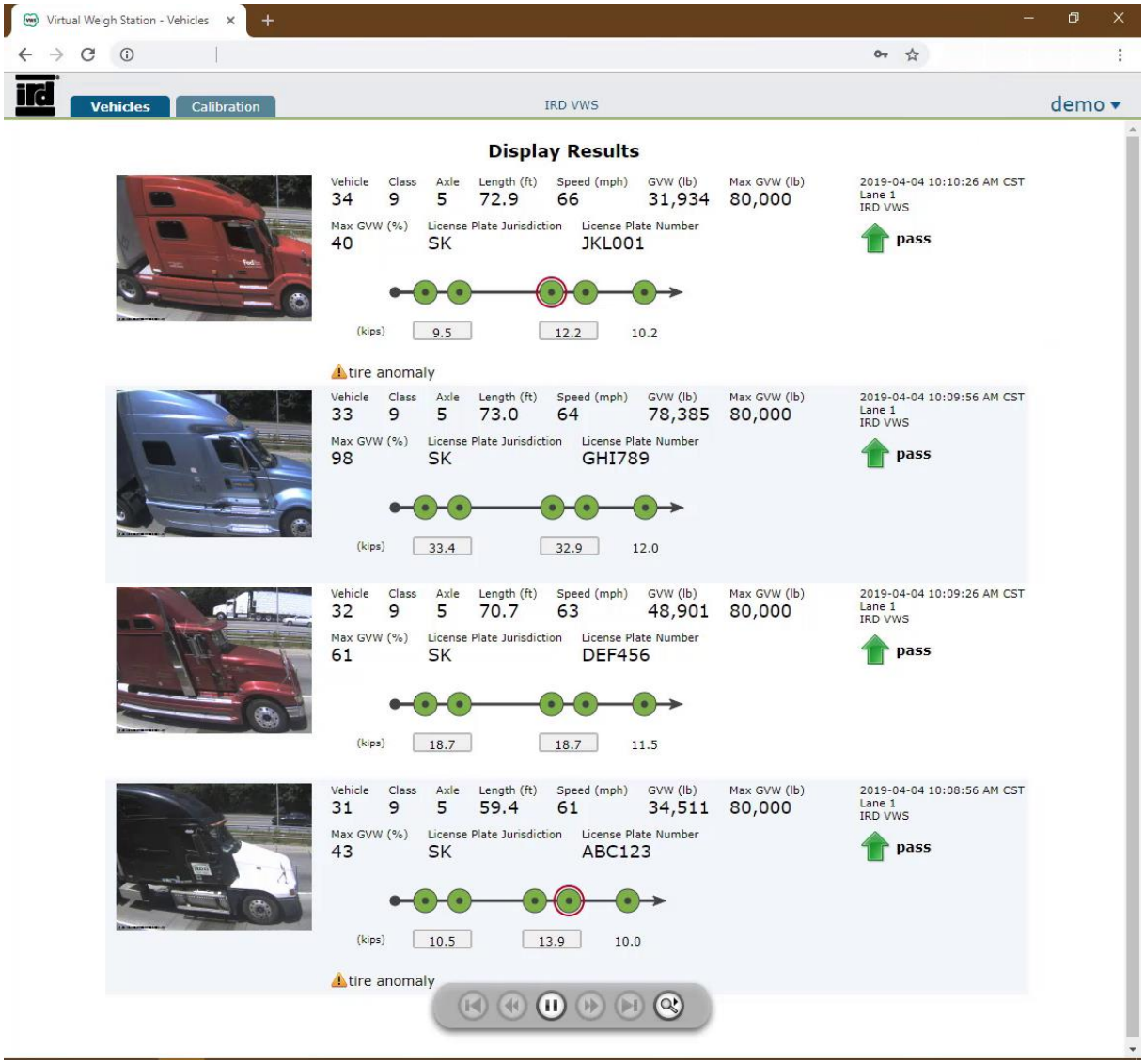

Figure 1 – VWS User Interface

As seen in Figure 1, a standard VWS will typically deliver the following information through individual vehicle records.

- Date and time of vehicle run.
- Gross Vehicle Weight (GVW) and Axle/Axle Group Weights.
- Vehicle class.
- Speed.
- Automatic License Place Reading (ALPR).
- Automatic Department of Transportation (DOT) number reading.

A VWS serves two main purposes. The first purpose is to screen potentially non-compliant vehicles. The second purpose is to collect uninterrupted, site-specific overload data that allows road owners to understand where, when and how vehicle overloads happen more frequently and severely, which can be a key aspect in planning and design effective control

strategies. To serve these two main purposes, a VWS basically combines high-end WIM system to one or more vehicle identification devices.

2.1. Electronic Screening (E-Screening)

VWS quickly became a tool for road safety inspections. With a few additional implementations, these stations could be used as efficient means to screen vehicles for safety status and credentials while being weighed. If potentially unsafe Commercial Vehicles can be diverted to fixed inspection facilities (like weigh stations), the vehicles could be further checked for safety problems under closer examination.

Traditionally in North America, vehicles could be selected for safety inspections based on an officer's experience and visual clues. This approach started to be more data-driven when technology allowed for automatic access to vehicle identification information to retrieve safety and credentialing indicators that can determine if the carrier has a history of poor safety performance. Currently, a VWS can be equipped with ALPR and USDOT readers that can be used for automated checks of a carrier or vehicle database, yielding an Inspection Selection System (ISS) rating. The ISS score is an algorithm created by the Federal Motor Carrier Safety Administration (FMCSA) that is based on the motor carrier's safety performance data. This score is used as a decision-making criterion that guides the selection of vehicles for inspection.

During e-screening operations, when trucks participating in the program drive through an accredited inspection location, their safety credentials are checked and, if considered satisfactory, an electronic signal (e.g. message on a transponder or smartphone) tells the driver to continue the trip without entering the inspection facility. Otherwise, a message can also indicate the mandatory regular entry at the inspection site.

Every individual state will operate on their own rules for e-screening programs. Several states have a random five percent pull-in rate for qualified trucks, regardless of their ISS score. Also, it is common that participating trucks get an automatic message to enter the inspection stations if they occasionally have been placed out of service by FMCSA.

2.2. Inspection Verification – CVSA Decal Reader

The Commercial Vehicle Safety Alliance (CVSA) is an association of state officials responsible for enforcement of motor carrier safety laws in Canada, the United States and Mexico. Another indicator that can be used in integration with mainline WIM operations is the inspection decal by CVSA).

These inspection decals indicate that the vehicle has passed a CVSA safety inspection. Recently, new technology offered the opportunity to automate the task of checking these decals as the vehicles drive through WIM stations, complementing the pre-selection process in advance of a fixed inspection facility. Vehicles with expired decals may be prioritized for inspection, which can potentially improve the effectiveness of enforcement activities.

3. Tire Inspection

There is a clear and direct relationship between safety and tire pressure and condition. This has driven the adoption of tire safety screening as an additional feature of North American

Commercial Vehicle enforcement programs. This includes the automatic detection of potentially dangerous tire anomalies and the use of advanced multi-platform load scales that provide individual wheel weights that could indicate weight distribution issues.

Tire safety screening provides a wide range of tire-related data for fleet managers, drivers, and law enforcement. Monitoring, identifying, and notifying drivers of tires tire anomalies allows for not only early detection of potential safety issues, but also delivers the data needed to proactively address efficiency issues. Tires that are underinflated for the load being carried result in increased rolling resistance and increased fuel consumption and greenhouse gas emissions.

3.1. Tire Anomaly and Classification

The Tire Anomaly and Classification System (TACS) screens vehicles for tire anomalies in real-time and at highway speeds. TACS uses VectorSense tire sensors to measure tire footprints with a resolution within 10mm (Fig. 2). TACS identifies flat, missing, or mismatched diameter tires on a dual tire set, all conditions considered to present a high safety risk. TACS integrates with Weigh-in-Motion vehicle records for advanced weigh station automation. The integrated TACS system signals vehicles with an identified tire anomaly to report to the weigh station so that unsafe vehicles may be placed out of service.

Figure 2 – VectorSense Sensors and Electronics for TACS Installation, Osino, NV

Further to the standard TACS offering for identifying dangerous tire conditions, TACS has the ability to deliver additional data elements such as:

- Enhanced Tire Anomaly Detection (Suspect and Inefficient Tire Detection).
- Tire Type (Single, Dual, and Wide Based Tire).
- Tire Width.
- Lane Position.

Additional data elements can be integrated into the automated system to enable advanced enforcement and data collection capabilities.

TACS was developed with the main purpose of promoting road safety through the automatic identification of tire anomalies. The system tends to promote road safety not only because it is an unmanned system, but also because is capable of detecting flat tires or busted tires that are not noticeable in visual inspections.

3.2. Dual-Wheel Weighing

In 2021, the safety inspection agencies in North America saw for the first time the development of a "dual-wheel load scale" created to measure individual tire weights in a dual-tire configuration (Fig. 3). The individual tire weights measured by this new scale allow for specific tire safety inspections that associate the weight distribution with a tire rating and a safety status.

Figure 3 – Measuring Individual Wheel Weights within Dual Tire Configurations

Exceeding the weigh capacity of an individual tire is an out-of-service violation and a safety concern of the FMCSA, government agencies, and a safety concern for private industry. For many years, there were no method to accurately detect individual tire weights when tires are side-by-side (dual tires), resulting in this regulation being unenforceable and private industry driving unsafe vehicles damaging infrastructure.

This dual-wheel load scale introduced a new way of using vehicle weight information to address a safety violation. This means a first step in acquiring detailed and reliable weight information from axles with dual tires, which may in the future be incorporated into WIM sensors and devices.

4. Combining WIM with Tire Inspection Technologies – Case Study of Nevada Department of Transportation

The State of Nevada's Vehicle Size and Weight Enforcement Program is an example of how Weigh-in-Motion (WIM) has gradually evolved as part of road safety programs in North America. The Nevada VWS sites (Fig. 4) illustrate how combined screening technologies meet the objectives of the state's Commercial Vehicle size and weight enforcement program.

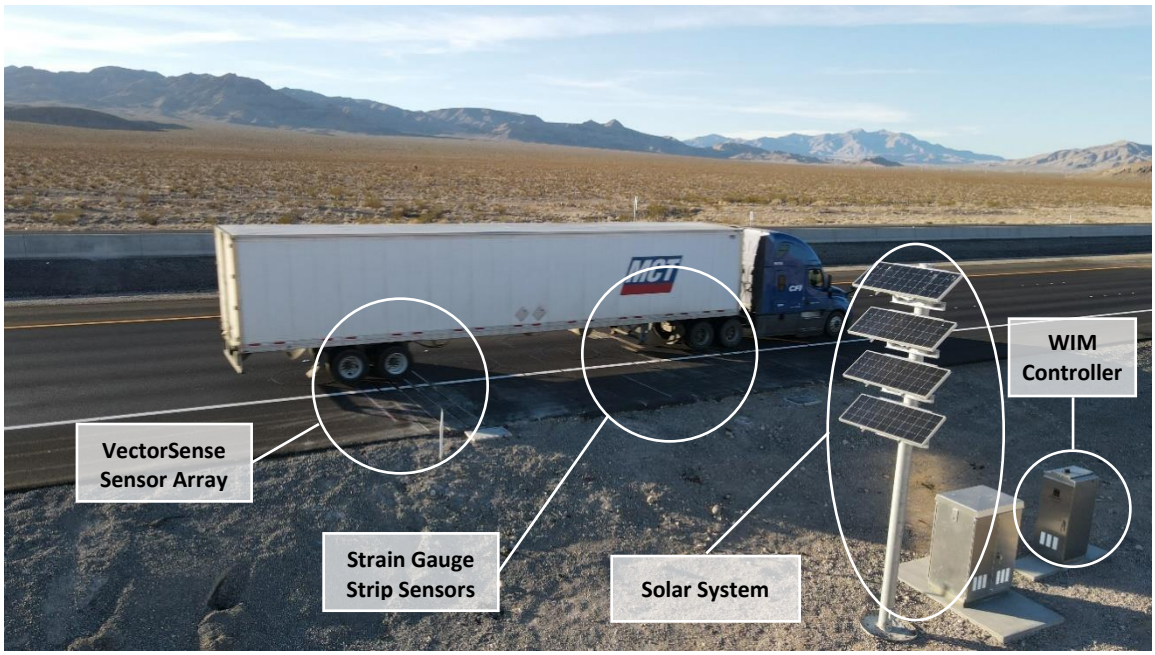

Figure 4 – Osino, NV Virtual Weigh Station

4.1. Strain Gauge Strip Sensors

The WIM installations in Nevada utilize Intercomp's strain gauge strip sensors in a double-threshold (4-sensor) configuration for load measurements. The sensors maintain accuracy under the wide temperature ranges typical of the sites. The Nevada sites conform to the ASTM E1318-09 Type III specifications for WIM accuracy, a standard commonly applied to Commercial Vehicle enforcement applications in North America. The Osino, Nevada, westbound drive WIM lane measured Gross Vehicle Weight with an accuracy of ± 4.5% for 95% of vehicles after initial installation and calibration.

4.2. Integrated Tire Anomaly and Classification System

The WIM system is integrated with TACS for vehicle screening. The WIM measurements and TACS information are used as the basis for selecting vehicles for enforcement. The WIM and Tire Anomaly screening results are appended to vehicle records that may be accessed via the internet using IRD's Virtual Weigh Station software. This allows enforcement personnel to monitor the site remotely and select vehicles for mobile enforcement using portable scales. When first deployed at the Osino NV site, TACS identified 2% of all commercial vehicles passing through the VWS as having dangerous tire conditions.

4.3. Operating a VWS in a Remote Location

In recent years WIM controllers with low power requirements have enabled systems to operate autonomously where there is no connection to the power grid. In the past these have been primarily WIM data systems, but the addition of a cellular modem for connection to the internet it is also possible to run a VWS for enforcement applications in a remote location without connection to mains power. Four 140-Watt solar panels and a battery storage system were required to provide reliable power to the system components, including the WIM sensors, TACS, sideview camera and system electronics.

4.4. Data analysis

WIM and TACS data from the site enable the ability to make informed decisions from enforcement practices to infrastructure and maintenance operations. At the Osino NV site over an 8-week period in early 2023, 631 tire anomalies we identified. This amounts to approximately 1.6% of commercial vehicles having a dangerous tire condition. Weight Violations were observed at 5.0% over the same duration. Observing the trends in this data from a day of week perspective can enable improvements in enforcement practices by identifying statistically when weight compliance would be most effective. In Figure 5, it is observed that there are relative trends in weight violations by day of week, while tire anomaly violations remain consistent suggesting they are of more random nature.

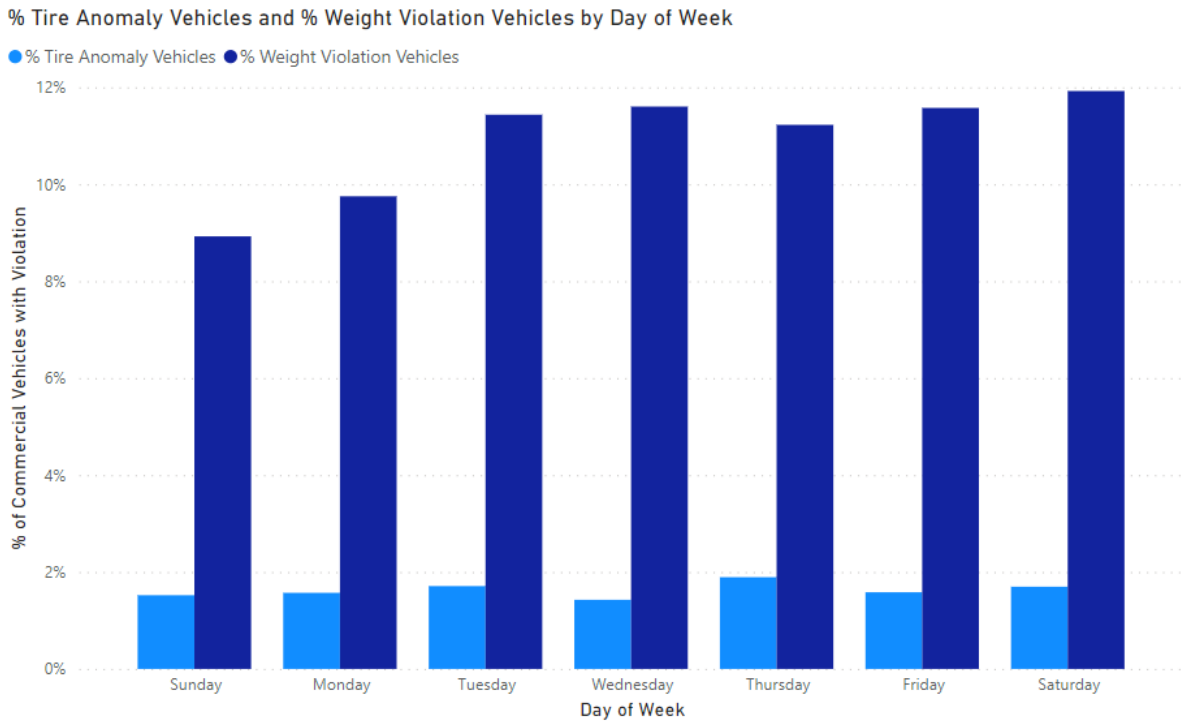

Figure 5 - % Tire Anomaly Vehicles and % Weight Violation by Day of Week

5. Discussion and conclusion

WIM systems have become well established worldwide for screening vehicles in advance of inspection stations. Today's systems continue to develop as new sensors and scales are developed and additional technologies are integrated with WIM to improve selection of vehicles for enforcement activities. This is increasingly being done remotely to enable improved safety and road infrastructure protection on secondary routes and in locations far from fixed inspection facilities. The integration of tire anomaly detection systems with WIM systems allows for the early detection of tire problems, such as underinflation, overloading, and irregular wear. This can help prevent tire failures and reduce the risk of accidents.

The integration of tire anomaly detection systems with WIM systems can also provide better data analytics, allowing for more accurate and timely analysis of road safety performance and trends. This can help road agencies make more informed decisions about how to improve road

safety. By automating the detection of vehicle overloads and of tire anomalies, road agencies can increase the efficiency of enforcement activities and prioritize their resources and improve overall enforcement outcomes.

Previous research indicate has that vehicle overloading may have serious implications on the risk of rollovers, brake failures and crashes caused by locked wheels, such as “plow out” (when the steering wheels are locked and the driver can’t steer), “jackknife” (when the tractor rear wheels are locked and the tractor spins) and “trailer swing” (when the trailer wheels are locked causing the trailer to spin). Further awareness about the risk of overloaded vehicles being a factor in road crashes can motivate the development of future applications where WIM data is used directly to support the identification of vehicles with a particular high risk of accidents caused by overloading or inappropriate load distribution.

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