6th International Symposium on
Heavy Vehicle Weights and Dimensions
Saskatoon, Saskatchewan, Canada June 18 - 22, 2000

# PHOTO WEIGH-IN-MOTION: CONCEPTS AND APPLICATIONS

Session Title: ITS and Vehicles

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## ABSTRACT

This paper discusses the technological aspects and applications of Photo Weigh-in-Motion designed to assist in the enforcement of commercial vehicle operations and to protect road infrastructure assets. The Photo WIM concept involves the merging of two existing technologies: WIM and photo enforcement. The primary function of the Photo WIM System is to detect vehicles that are of interest to the weight enforcement or planning agency and capture an image of those vehicles. The many applications of Photo WIM provide transportation agencies with the enabling technology to significantly enhance the enforcement of commercial vehicle weights and dimensions with minimal increases in personnel.

Photo WIM operates in a similar fashion to photo radar or red light camera systems. A Photo WIM system can be installed in mainline or remote locations in either a permanent or portable application to monitor commercial traffic at a particular location in the road network. WIM sensors are used to measure vehicle weights and dimensions and a camera is used to capture and store a photographic image of the vehicles of interest. If digital images are used, the image can be immediately communicated electronically to a central office for real time deployment of enforcement personnel.

The many applications of Photo WIM provide transportation authorities with tools to enhance the transportation system and protect the highway infrastructure.

## 1.0 INTRODUCTION

The use of video technology in combination with Weigh-in-Motion is a concept that has been in existence since the mid-1980's. With dramatic improvements in video and computing capabilities, the uses of Photo WIM have expanded considerably in recent years, and the future potential of this technology is extensive. This paper explores the common applications of Photo WIM that are currently in use, in addition to some recent developments and future concepts for the technology.

The many applications of Photo WIM provide transportation agencies with the enabling technology to significantly enhance weight enforcement and infrastructure planning effectiveness with minimal increases in personnel. The integration of Photo WIM into a tactical weight enforcement strategy holds significant benefits in terms of improved commercial vehicle safety, ensuring equitable competition in the commercial carrier industry and protecting public road assets from excessive and accelerated damage caused by overloaded commercial vehicles.

## 2.0 BACKGROUND AND NEED

Road infrastructure assets are under increasing pressure from government budget constraints, increasing vehicle weights and dimensions, wide spread reliance on just-in-time delivery, a paradigm shift in the transportation of bulk commodities from rail to road due to rationalization of the grain handling system, and economic diversification initiatives within many jurisdictions. To make optimal use of constrained road infrastructure asset management budgets, there is a clear need for technologies that help preserve road infrastructure assets while encouraging innovation and efficiency in the commercial trucking industry.

Photo WIM has several applications in commercial vehicle weight enforcement, infrastructure development, and road asset maintenance planning. Photo WIM can be used to augment permanent weigh station operations by providing images for mainline WIM pre-screening systems, monitoring vehicle compliance to WIM sorter traffic signals and traffic signs, and for monitoring weigh station evasion routes. Photo WIM may also be deployed in conjunction with mobile and remote weight enforcement as a pre-screening system, or as an automated stand alone monitoring system on remote routes. Data collected by Photo WIM can provide weight enforcement agencies with a visual record from which to engage in discussions with particular carriers detected as chronic violators, or to assign preferred carrier status. Photo WIM may also be deployed in support of transportation planning activities to assist traffic engineers to evaluate future capital developments or help road asset managers plan preservation programs across specified segments of the road infrastructure. Other applications of Photo WIM include urban weight enforcement and concentrated haul road weight enforcement.

## 3.0 PHOTO WIM SYSTEM DESCRIPTION

There are two primary Photo WIM system configurations discussed in this paper: Level I Photo WIM and Level II Photo WIM. The type of Photo WIM system deployed will be based on the level of information required to identify an event of interest. The primary difference between the two systems is sensor configuration, processor electronics and degree of user integration. The choice of system technologies is based upon the violation criteria of the installation site and the enforcement goal of the agency. The video camera employed in the Photo WIM system may be black and white or colour, digital or analog. Photographic paper can also be used to store images, however this technology is not discussed in this paper. The use of black and white video is more economical and requires less image storage capacity than colour video. Infrared illumination can be used with black and white cameras making them well suited for nighttime use. Digital cameras are more expensive than analog cameras, however, they provide higher resolution imagery. The choice of video system configuration is determined by site conditions and system function. Although the video camera provides a constant feed of images to the video card, the Photo WIM system can be programmed to capture and store only those vehicles that exceed pre-determined selection criteria.

### 3.1 Level I Photo WIM System

The Level I Photo WIM System is intended to provide a low cost method for monitoring and enforcing truck routes that are banned to commercial truck traffic. Because the number of trucks using a banned road can be assumed to be low, a Level I Photo WIM System that can distinguish cars and light trucks from commercial vehicles provides a cost effective enforcement alternative to labour intensive mobile weight enforcement.

The Level I Photo WIM System is able to select vehicles based on number of axles using smart loop technology or based on a weight threshold using axle detection sensors. Smart loops can be employed when violations are determined by classification alone. Alternately, an axle sensor threshold may be used to approximate vehicle weight. The signals generated by the axle detection sensors determine if the vehicle is in excess of the allowable weight for the roadway. The vehicle detection loops and/or axle sensors provide a signal output to the sensor interface. If the selection criterion is met, a photo trigger is sent to the video card and a video image is captured and stored to the hard drive with a time stamp. This system provides traffic management and enforcement personnel with visual identification of commercial vehicles that are using banned roads.

Figure 1 illustrates the primary components of the Level I Photo WIM System. The Level I Photo WIM System consists of vehicle detection sensors, a video camera, computer, and external sensor interface. Housed within the computer is a video card and a data transfer device (modem or network device). A full range of axle sensors can be employed including DYNAX®, piezoelectric, smart inductive loops and/or WIM scales. The choice of sensor to

be deployed with the system is dependent on budget and the degree of vehicle classification and weight enforcement that is desired.

An enforcement officer at a remote site may view vehicle images captured by the Photo WIM System. There are two methods available to transfer and display images to the operator. Real time images can be transmitted via an Internet link (ADSL, cable, ISDN) if the infrastructure for such a connection is available. Alternately, the stored images can be transferred in batch mode from the site computer to the operator station through a modem. Video transmission via an Internet link provides the added ability for an operator to monitor real-time road and traffic conditions (i.e. snow removal, accidents).

The primary benefits of the Level I Photo WIM System are its low cost and simplicity. However, the use of a commercial computer restricts the users' ability to configure the sensor thresholds and settings from a remote location. Additionally, only simple sensor configurations can be deployed, therefore the degree of vehicle weights and dimension measurement precision is limited.

3.2 Level II Photo WIM System

The Level II Photo WIM System has a range of applications for commercial vehicle operations (CVO) and infrastructure planning, including identifying heavy vehicles that do not obey traffic control signals in and around automated weight enforcement stations, enhanced data collection programs, enhanced pre-screening capabilities at automated enforcement stations, remote weighing facilities and weigh station evasion route monitoring. Because the Level II Photo WIM System employs purpose built WIM electronics, a full range of classification and weight sensors can be used to define the target vehicles. The criteria used to identify a trigger event can be more complex, due to the increased computing and sensor hardware capabilities. Violations may be based on weight compliance, classification compliance and/or vehicle dimensions. Additionally, the customised electronics and software provide the operator with detailed vehicle record information and the ability to configure, edit and perform diagnostics remotely.

As seen in Figure 2, the Level II Photo WIM System consists of a WIM electronics, video camera, modem, network connection, interface cards for a wide range of axle sensors and WIM scales and a video card. The Level II Photo WIM System will typically use a combination of loops, axle sensors and WIM scales to form a vehicle record. Some standard layouts are loop – WIM scale – axle sensor – loop for precise weight enforcement measurements, or loop – piezo – piezo – loop for weight data collection accuracy. Other sensor configurations can be implemented according to the user requirements. The sensors interface to a purpose built WIM electronics unit. A video camera interfaces to a video card housed within the electronics.

A typical Level II Photo WIM System vehicle record could contain the following information:

- Time
- Lane
- Speed
- Axle Weights
- GVW
- Axle Spacings
- Group Indicators (i.e. single, dual, tandem, axle groups)
- Length, Overheight
- Single/dual Tire Indicators

The WIM software compares the vehicle record against the selection criteria of the site. If the vehicle record indicates that the vehicle is of interest, the video card is triggered to store the vehicle image in addition to the vehicle weights and dimensions record. The data can be transferred to a remote location for interpretation and processing by Internet, by a local network connection or in batches by modem.

Another advantage to the Level II Photo WIM System is the ability to remotely change enforcement thresholds such as sensor thresholds, trigger thresholds, sensor configuration and violation criteria. This ability to remotely change enforcement thresholds provides considerable user utility and flexibility for such applications as remote haul road enforcement, spring weight restriction enforcement, and safety management enforcement.

There are four primary applications for the Level II Photo WIM System:

- Enhanced commercial vehicle data collection;
- Pre-screening at weight enforcement facilities;
- Remote controlled weight enforcement facilities, and;
- Private commercial/industrial applications.

3.2.1 Enhanced Commercial Vehicle Data Collection

Video imaging enhances commercial vehicle data collection for maintenance and planning activities and can be used to improve communication with carriers. A Photo WIM System is added to a new or existing WIM data collection site. When user defined criteria are met, the vehicle image and vehicle record are stored. Some common trigger criteria include non-compliance to weight or dimension regulations, or classification-based triggers. For data collection the visual component of the vehicle record can be used to:

- Determine qualitative commercial sector information including the traffic mix a single industrial sector generates and the degree of non-compliances generated by commercial sector. Photo WIM can be used to augment interpretation of data collected at permanent sites. Often, data collected at a single site is used to approximate the traffic patterns for a larger portion of the road network. Traditional WIM data is collected without knowledge of localised anomalies that could skew the extrapolated data. In this case it is useful to know if a local industry (i.e. plant, mill, etc) near the site is contributing a large number of a certain class of vehicle to the overall traffic mix. Knowledge of the localised traffic patterns is then used to more accurately extrapolate the data. For example, if a WIM Data Collection System is installed near a mining facility, the data may be skewed to the particular location on the highway and may not accurately represent the general traffic on the road. By observing the vehicle images, in addition to the WIM data, the degree to which the data is skewed can be quantified and corrected for in the extrapolation. Additionally, Photo WIM data can provide valuable insight into the traffic loadings for mechanistic-empirical road performance modeling techniques

and analysis of unexpected failures (Berthelot, C., Loewen, T., Taylor B., "Mechanistic Load Equivalencies using Weigh-in-Motion", 6th International Symposium on Heavy Vehicle Weights and Dimensions, 2000).

- The use of Photo WIM combined with a data collection site inexpensively provides an additional means of monitoring the performance of companies participating in a Preferred Carrier Program. The Photo WIM system is set to capture the images of vehicles with weight or dimension violations. Companies participating in a Preferred Carrier Program will have their performance monitored through the Photo WIM System. If repeated offences by a carrier are discovered, action can be taken regarding their Preferred Carrier Status. For jurisdictions not participating in such programs, the Photo WIM data can be used to engage in dialogue with carriers that are chronic offenders.

### 3.2.2 Pre-Screening at Mobile Weight Enforcement Facilities

Photo WIM is a useful tool for pre-screening vehicles at permanent or mobile weight enforcement facilities. Mobile weight enforcement typically involves a patrol car or specialised weight enforcement unit that deploys weight enforcement checks at temporary facilities such as roadside rest stops. Photo WIM can be used to knowledgeably plan temporary enforcement deployments to enhance their effectiveness and improve efficiency.

- Planning: Photo WIM can be installed at location(s) near the temporary weight enforcement facility. The data collected at these sites can be used to assist the enforcement officials to choose the optimum times and locations to perform the enforcement, thereby increasing the effectiveness of enforcement activities. Additionally, if the photo data indicates that certain carriers are consistently out of compliance, the enforcement officials may choose to target their enforcement activities on those carriers.
- Temporary Enforcement Efficiency Enhancement: A Photo WIM system can be installed at a permanent or temporary data collection site. The system captures the images of all vehicles that are in violation of the local regulations. The images are transferred in real time to an officer, either directly or via an operations centre (or weigh station). The officer is then able to focus the enforcement efforts on those vehicles that are most likely out of compliance.

### 3.2.3 Enhancement of Permanent Weight Enforcement Facilities

At permanent facilities, Photo WIM provides evasion route monitoring, monitoring of driver movements in automated weigh station facilities and sorter decision override. In all of the above cases, the Photo WIM System captures the images of vehicles of interest and displays these images to an operator at a weigh station facility.

- Truck in WIM Lane Monitoring: At automated weigh stations using WIM and/or AVI to pre-screen vehicles, it is important for operators to monitor the drivers' compliance to signing directing them to a WIM lane. Typically one lane per direction is instrumented with the WIM sorting equipment, with the remaining lanes utilising a less expensive Automatic Vehicle Classification (AVC) system. All trucks are required to

travel in the right-hand (WIM) lane upstream of the weigh station. The AVC system can be connected to a camera system, with images of all commercial vehicles that are detected by the AVC System recorded and transmitted to the weigh station, accompanied by an alarm. In this way, the operators can identify vehicles that are attempting to illegally bypass the weigh station, and a patrol car may be sent to meet the violating vehicle.

- Vehicle Tracking: Another use of Photo WIM at a weigh station equipped with an Automated Sorter System is to improve the operator's ability to track the vehicles as they move through the weigh station. Based on the characteristics measured by the WIM sensors, the driver is directed to either report or bypass the weigh station. All vehicles that are required to report have their image captured and sent to the weigh station, so that the operator can anticipate which vehicles are approaching.
- Sort Decision Compliance Monitoring: Photo WIM can also be used to monitor and enforce the drivers' compliance to the sort decision. If a non-compliant vehicle is directed to report, then is detected in the bypass lane by in-road sensors, an alarm is sounded and an image of the vehicle is captured. Using the vehicle image, the operator can send an officer to apprehend the driver.
- Credential Clearance/Sorter Override: Another use of this system within the weigh station is to allow the operator to override the automated sort decision, based on a visual identification of the vehicle. There are two common scenarios for this application. The first application uses the vehicle image to perform credential clearance. If the vehicle is within weight and dimension compliance and is a carrier that is recognised to have compliant credentials, but does not have an AVI transponder, the operator can manually override a report decision. Alternately, if the system automatically permits a vehicle to bypass, but the operator identifies the vehicle through the photo system as being required to report (i.e. to confirm that a previously identified safety issue has been corrected), then the bypass signal can be overridden and replaced with a report message.
- Evasion Route Monitoring: Where an evasion route exists near a permanent weight enforcement facility, Photo WIM can be employed to permit mobile enforcement on the evasion route. A Photo WIM System is installed on the evasion route and all vehicles using the route are weighed and classified. The operators at the nearby station can set the threshold of the Photo WIM System to capture images of vehicles that exceed the legal weight limit. These images are displayed to the operator at the permanent weight enforcement facility, who is then able to dispatch an officer to bring the violating vehicle into the station for weighing at the static scales.

### 3.2.4 Remote Controlled Weight Enforcement Facilities

The addition of a camera system allows effective remote operation of a weighing facility. For discussion purposes two scenarios will be considered. In the first scenario a station operating on two sides of the highway from a single enforcement building is considered. Only one side of the facility is manned. The second remote facility application is for low or medium volume stations for which it is not cost effective to provide full time staff. With the

aid of video, the facility is then run from a central location; with no personnel required at the remote weigh station.

For a two-sided facility, manned from only one side, the operator is able to directly view only some of the activity at the remote side. Cameras located at the WIM indicate to the operator which vehicles are required to report to the static scale. The cameras can also be used to assist in the weighing process on the static or SSWIM scale. At some facilities cameras are used for document viewing, thereby reducing the number of times that either an officer is required to go the remote side or a driver must come the enforcement building.

In the second scenario, the facility is operated from a remote location. This is well suited to low volume stations that do not warrant full time staffing, but which require weight enforcement. Cameras are installed around an unmanned weighing facility, such that the actions of the driver are monitored. The mainline Photo WIM is used to capture the images of commercial vehicles that do not report. The captured image and vehicle record are sent to the remote manned location, where an officer can be dispatched to meet the offending vehicle and direct it for further weighing. For vehicles that report as directed, the camera can be used to monitor the weighing and parking lot activities, and provide the opportunity for an operator to offer assistance (through voice communications) as necessary. In this scenario, a camera would also likely be present for document viewing. In an ideal situation, a number of low volume weigh stations would be operated from a single manned station or central location. A Photo WIM System can also be implemented as a low cost weigh station facility located on an evasion route, or to extend the effective enforcement hours of a low to medium volume facility.

3.2.5 Private Commercial/Industrial Applications

There are number of potential commercial and industrial applications for Photo WIM technology. One such application is automated unloading facilities such as waste disposal facilities, gravel pits, hot mix asphalt plants, mining facilities, etc. By using either static or WIM technology, the vehicle can be automatically identified and weighed as it enters the facility and again when it leaves the facility. A DSRC transponder may also be used to identify the vehicle for billing purposes and the weight difference is used to determine the amount of the billing. A video system can be added to the proposed configuration to help automate the unmanned operation. The captured images can be used for verification if a customer has a disagreement with the facility operator. The camera can also be used if there is a failure with the DSRC technology or discrepancy in the weight. Additionally, the camera images can be used for the billing of vehicles without transponders. Such scenarios include facilities where the facility owner pays the carrier for transportation services and/or where the carrier pays the facility for use of the facility and it is impractical to instrument every vehicle that uses the facility. The 407 toll road in Ontario, Canada uses a similar concept in capturing the images of vehicles without transponders and billing those vehicles based on the license plate number extracted from the camera image.

### 3.2.6 ITS Traffic Management System

ITS Traffic Management Systems are designed to improve the traffic flow efficiency of the network. Traditionally, traffic management systems have been limited to large traffic volume facilities such as Freeway Management Systems. However there is a clear need to improve traffic flow efficiency across all urban road systems whether that be on a highway or a city street. The general concept is that a Traffic Management system is designed to gather information about the current traffic flow. The gathered information is processed and used in a number of different ways:

- Dynamic adjustment of traffic signal timing to resolve congestion
- Dispatch of emergency equipment to a traffic accident location
- Evaluation of road hazard conditions to determine if sanding or snow removal is required
- Provision of driver advisories for traffic delays and alternate routes

A Photo WIM System can be designed to provide real time or near real time images of the current traffic volume and road conditions. To facilitate this, the camera is used like a Web Cam is used on the Internet. The camera images are viewed in a Traffic Management Operations centre or at a maintenance facility and are used in conjunction with the other technologies available in the overall Traffic Management System.

### 3.2.7 Vehicle Characteristic Evaluation

Video imaging and WIM can be used to provide additional information about vehicles for CVO or toll facilities. Determination of oversize dimensions, such as vehicle width and overhang, has not been possible with traditional road sensors. Video imaging of the vehicle provides a range of additional classification information, such as the ability to distinguish between busses and RVs or the type of trailer being pulled by a truck (i.e. flat deck, tanker or van trailer). This information is valuable for oversize vehicle permitting or to extend vehicle classification schemes.

### 3.2.8 Commercial Vehicle Safety Applications

In the area of safety, thermal imaging could be used to look for axle or braking problems similar to the existing train axle monitoring facilities. The camera systems installed for weight enforcement or data collection could also be used to detect hazards such as flat tires, loose loads, hanging debris, leaking trailers, etc.

## 4.0 CONCLUSIONS

Photo WIM technology has several applications for the transportation market. Photo WIM draws upon two accepted technologies; video and WIM, and combines them to extend the usefulness of both technologies. Current uses of Photo WIM include enforcement of truck route violations, enhancement of automated weight enforcement facilities and

improvements to data collection initiatives. Applications that are forthcoming include remote weigh stations, unmanned waste terminal facilities and more flexible toll audit systems. The use of proven technology forms a sound basis for the further expansion of Photo WIM. With the increasing limitations on budgets for highway construction, maintenance and planning, Photo WIM is an increasingly valuable tool to extend budgets and utilise funds in the most efficient manner.

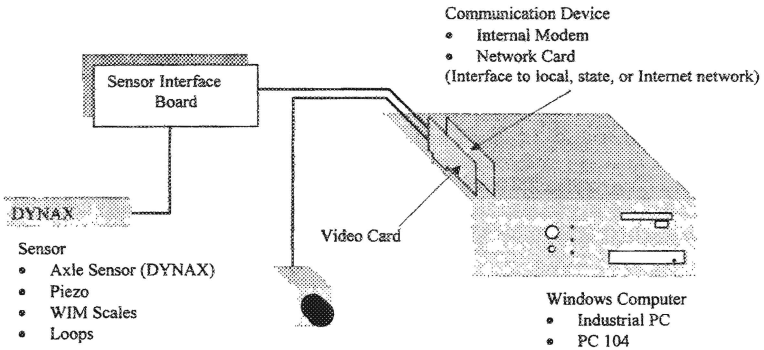


Figure 1: Level I Photo WIM

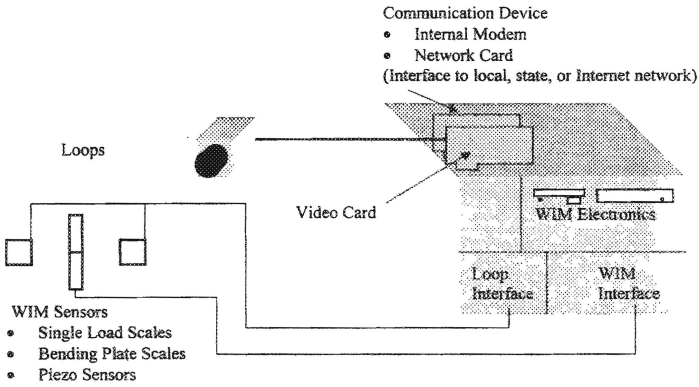


Figure 2: Level II Photo WIM