REAL WORLD APPLICATIONS OF VIRTUAL WEIGH STATIONS

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Abstract:

In these uncertain times, protection of roadway infrastructure and reduced vehicle emissions are paramount to the taxpayer and the environment. There is an exponential relationship between truck axle overloading and pavement damage. A 10% increase in axle overload can result in up to a 45% increase in pavement damage* [1]. Furthermore, as active enforcement of overloaded trucks increases, non-compliance with truck loading regulations decreases [2].

With conventional ramp weigh stations, heavy trucks are directed to pull into a weigh station site and required to either slow down or stop for further inspection. When heavy trucks can continue on the highway unimpeded, there is a significant reduction in vehicle emissions and fuel consumption, as compared with the acceleration and deceleration pattern which is typical of a conventional weigh station interaction [3].

Additionally, the reduction in the number of overloaded axles results in pavements lasting longer, with less frequent rehabilitation and reconstruction; this provides a further environmental benefit from the reduced maintenance requirement.

Unlike conventional ramp weigh stations, Virtual Weigh Stations and Mainline Weigh-In-Motion (WIM) systems make continuous highway travel possible for trucks that are compliant with weight regulations. This paper focuses on Virtual Weigh Stations, which are increasingly being used to reduce the percentage of overloaded trucks, thereby diminishing excessive vehicle emissions and damage to pavement infrastructure. The Virtual Weigh Station provides a way to unobtrusively monitor commercial vehicle traffic on highways and urban streets. This paper discusses real world applications of the Virtual Weigh Station in diverse locations such as Saskatchewan, Northwest Territories, New York, and Wisconsin.

Virtual Weigh Stations are Weigh-In-Motion systems that provide vehicle records for enforcement, traffic surveillance and/or data collection in real time over a computer network connection. The system automatically weighs vehicles as they travel at normal speeds along a roadway, classifies them based on weight and axle spacings, determines when vehicles are in violation of regulations, produces records of commercial vehicles, and provides a display of these records on a computer with a network connection to the system.

* 4th power approximation of the AASHTO load equivalency equation: for a 10% increase this yields a ratio of $(1.1/1.0)^4 = 1.4631$ or approximately 45%

Introduction

Virtual Weigh Stations (VWS) are Weigh-In-Motion systems that provide vehicle records for enforcement, traffic surveillance and/or data collection in real time over a computer network connection. The Virtual Weigh Station provides a way to unobtrusively monitor commercial vehicle traffic on highways and urban streets. The system automatically weighs vehicles as they travel at normal speeds along a roadway, classifies them based on weight and axle spacings, determines when vehicles are in violation of regulations, produces records of commercial vehicles, and provides a display of these records on a computer with a network connection to the system. The system is made up of Weigh in Motion (WIM) sensors, a signal processorr, an optional image capture system and a network server.

The use of a Virtual Weigh Station system benefits the transportation agency, the trucking industry, and the general public in many ways, including:

- reduced traffic flow disruption when compared to conventional weigh ramp stations, resulting in reduced fuel usage, decreased emissions and improved safety.
- better data collection to improve road design.
- protection of pavement and bridge structures against premature damage due to overweight vehicles.
- policing of trucks on secondary roads attempting to bypass main inspection stations.
- better identification of potential violators, leading to more efficient enforcement.
- increased resources to focus on safety issues.

The Limits to Conventional Inspection Stations

As the volume of commercial vehicles using the highway infrastructure increases worldwide, the capacity of existing conventional weighing and inspection stations to effectively monitor and enforce regulations is being exceeded. Trucks backed up waiting to be weighed cause disruption to the carriers' delivery schedules, fuel wastage and increased emissions due to idling, deceleration and acceleration while waiting in the stop and go queue. Safety issues arise due to the large number of heavy vehicles exiting from and merging back into the main traffic stream. Vehicles with violations are able to bypass the inspection station when it reaches maximum capacity and has to temporarily close.

Additionally, conventional ramp weigh stations are traditionally built only on major highways and are located outside urban areas. This means that urban commercial traffic is largely unscrutinized and that commercial traffic can avoid inspection by using secondary highways.

Building more inspection stations or expanding the capacity of existing stations would be costly in terms of land requirement, construction costs, personnel to staff, and increased environmental impact.

A viable and complementary solution is the use of virtual weigh stations.

Virtual Weigh Station

A Virtual Weigh Station is “virtual” in the sense that the main components accessed by users exist on the Internet, rather than as physical buildings, scales and ramps.

A network of multiple virtual weigh stations can be integrated into a system that an agency can use to monitor sites throughout its area of jurisdiction. This network can be as large as necessary to cover the subject area (refer to Figure 1 - Multiple VWS Site Map). A large area can be subdivided as many times as necessary to provide convenient management by the user (refer to Figure 2 - Regional Site Map).

VWS site information is available to any authorized user with network access.

Site information is presented on a standard Internet browser web page (Figure 3 - Virtual Weigh Station Display).

For each lane at a VWS site, the browser page displays a row of vehicle images sequenced in the order that they passed over the WIM sensors (Figure 4 - Lane display).

Each lane display can be set to show either all commercial vehicles or only those vehicles that are potentially in violation of regulations.

Any vehicle displayed can be selected to display details in the vehicle record (Figure 5 - Detailed vehicle record). The detailed vehicle record includes the following information:

- **Vehicle image** – a larger format image of the vehicle.
- **Record number** – a sequentially assigned record number
- **Lane** – the lane that the vehicle was in when the record was created.
- **Speed** – the vehicle speed.
- **Recorded GVW** – the Gross Vehicle Weight calculated by the WIM system.
- **18K-ESAL** – the 18,000 pound equivalent single axle loads for the vehicle.
- **Max GVW** – the maximum allowed GVW for a vehicle of this class.
- **Length** – the overall length of the vehicle.
- **Date & Time** – the date and time of day (to the nearest hundredth of a second) when the vehicle entered the WIM system.
- **Class** – the vehicle classification assigned by the WIM system.

- **Threshold GVW** – the Gross Vehicle Weight above which a vehicle will be displayed as “overweight” by the virtual weigh station.
- **Schematic Diagram of the vehicle** – includes the vehicle length, the approximate position of each axle and the approximate axle weight.
- **Axle Information** – a table of detailed information for individual axles. Information for each axle includes the following:
    - **Axle number** – counting from the front of the vehicle.
    - **Separation** – the distance from the previous axle.
    - **Weight** – the axle weight as calculated by the WIM scales. Any axle above threshold weight is displayed with a grayed background.
    - **Threshold Weight** – the weight for this axle, above which a vehicle will be displayed as “overweight” by the virtual weigh station.
    - **Allowable** – the maximum allowed weight for this axle.
- **Warnings and Errors** – if one or more vehicle status or potential violations warnings have been detected, a message is displayed at the bottom of the record for each violation; if an error has occurred in weighing the vehicle, an error message is displayed at the bottom of the record.

Real time & historical records

The user display provides access to both real time and historical vehicle records.

The real time display is updated within a few seconds of a vehicle passing over the WIM sensors and may be paused or updated at any time.

The historical function displays previously recorded data for a specified time and date.

Screening

The screening for vehicles with potential violations can be based strictly on weights and dimensions, or can be combined with identification based screening that looks at aspects such as safety history, credentials, and permits.

The most basic use for a VWS is data collection, with the data used for planning, design, and evaluation of the highway infrastructure. This data can also be helpful in understanding the nature of trucking activity to develop more specific enforcement strategies and measure effectiveness of these strategies. During the planning stage, trends can be determined regarding traffic volume, traffic patterns, and overloading rates for specific vehicle types to determine when, where, and who to target during enforcement. The data can also be used for evaluation purposes to determine the short term and long term effectiveness of enforcement efforts in deterring overloaded vehicles.

VWS data can also be used for real time enforcement. Whenever an overweight vehicle is detected, an indicator alarm is activated in a patrol car downstream. The officer must visually identify the vehicle on the WIM sensors at the time of occurrence and then can bring the vehicle in for enforcement purposes. In a similar application for a multi-lane site, a pullout area for downstream of the WIM system may be used for enforcement. Since multiple lanes are being monitored, a changeable message sign can be used to display the lane number in which the violation has occurred.

With the addition of one or more cameras, the system can provide images of an overall side view of the vehicle, detailed images of the license plate or USDOT number markings. Advanced software can perform optical character recognition of either the license plate number or the USDOT number to identify the vehicle.

If the site is equipped with Automatic Vehicle Identification (AVI) capabilities, then the identification of vehicles registered in the AVI database can be determined. The system can query the database for safety and credential information on the vehicle and carrier, enabling quick processing of vehicles with a clear credentials record and comprehensive screening for any vehicle that may not have its credentials in order.

The system provides access to the information virtually anywhere and anytime, provided that a network connection can be established. The information is primarily used in one of two ways, either in real time or for historical review. In real-time, enforcement personnel positioned at a suitable downstream location can view each passing vehicle and target vehicles of interest for further enforcement. In a historical application, the data recorded over some period of time can be processed and violating carriers identified; follow-up enforcement activities such as warning letters or activity audits to encourage future compliance with weight regulations can then be performed.

System Components

The hardware for a VWS allows unobstructed traffic flow and is unobtrusive.

The WIM System Electronics are located next to the WIM sensors in a roadside cabinet. The System Electronics create and format vehicle data for a web server to display the vehicle records.

The electronics at a VWS site are housed in a weatherproof roadside cabinet.

The cabinet contains a standard rack mount for the system processor, video controller, network electronics, power supply and cabling terminations (Figure 6 - Virtual Weigh Station Enclosure and Electronics Rack.

The electronics include interfaces to the following components:

- Weigh In Motion Sensors
- Axle Sensors

- Inductive Loops
- Offscale Detectors
- Camera System (optional)
- Network communications gear

The electronics are an integrated modular design capable of processing signals from multiple types of WIM sensors (Single Load Cell scale, Bending Plate, Kistler Lineas Quartz sensors and/or Piezoelectric WIM).

The system processor collects and interprets the signals from the WIM sensors, processes these inputs into a vehicle record, and forwards the results to the system server.

The processor provides the following functions:

a) Weighs all vehicles traveling over WIM scales.
b) Classifies all vehicles traveling on all instrumented lanes of the highway.
c) Performs weight compliance analysis on vehicles in accordance with department or agency regulations.
d) Performs sorter operation in accordance with decisions based on weight compliance analysis, other violations (speeding, overlength, improper maneuver, sudden speed change, etc.).
e) Inserts sequence numbers for vehicle records to correspond to the sequence of arrivals at the WIM location.
f) Captures images for all vehicles (if there are cameras at the site).
g) Filters out all images of non-commercial vehicles and formats images for the Web server.
h) Performs data collection, data storage, and basic file management functions for collected vehicle information to be forwarded to the system server.

The VWS system can interface with industry standard vehicle imaging, license plate imaging and/or USDOT number imaging subsystems. Cameras may be mounted either above or beside the traffic lane, depending on the site layout. Infra-red, color and/or black & white cameras can be used to meet image requirements of the system.

The system is compatible with Automatic Vehicle Identification (AVI) dedicated short range communications equipment, as specified by the Heavy Vehicle Electronic License Plate (HELP) project, including communications ports and software.

The number of virtual weigh stations that report to the server is limited only by the storage capacity and available bandwidth of the server.

Environmental considerations

There are a number of areas in which Virtual Weigh Stations can provide a positive environmental effect:

Emissions Reduction:

A recent study in Oregon found the following reductions in emissions per million bypasses resulting from vehicles being weighed at highway speeds in normal traffic flow as compared to stopping at a conventional weigh station [3]:

- CO_2 – 583 tonnes (36.0%)
- NO_X – 5.33 tonnes (36.4%)
- CO – 1.6 tonnes (48.5 %)
- Hydrocarbons – .67 tonnes (46.3%)
- Particulate matter – .33 tonnes (67.1%)

Fuel savings were estimated at 336,000 liters per million bypasses. The travel time savings were estimated at 1.47 minutes per bypass or 24,500 hours per million vehicles.

As the study in this test assumed the test vehicle had direct access to the scales and thus made only a single stop with no waiting queue and no starts or stops in the wait queue, real world gains are likely to be significantly better.

Construction and Operations:

A VWS has a much smaller footprint than a traditional weigh station; all equipment fits within the normal highway right of way so no additional land is required. There are no ramps or buildings to construct, resulting in a saving both in the materials required and in the energy cost of the construction.

VWS operations can be conducted from a central location that can be anywhere with network access, so staff commuting can be greatly reduced when compared to traditional, more remotely located weigh stations. An operator can monitor a number of VWS sites, so personnel can provide coverage to a larger area of the highway network; this would become significant as the percentage of non-compliant vehicles decreases due to the increased enforcement coverage [5] that a VWS system allows.

Maintenance and Reconstruction:

Additional environmental savings come from reduced need for maintenance and rebuilding on road systems where a lower number of vehicles are overloaded.

Vehicles with overweight axles cause damage to pavement and bridge structures that is exponentially proportional to their weight. Accurate statistics on overweight vehicle operations are difficult to obtain because overweight vehicles tend to attempt to avoid detection. A sampling of available studies indicates that on unsupervised highways, both the percentage of the commercial traffic stream that is overloaded and the average amount of overloading per overweight vehicle is greater than on a highway with enforcement of weight regulations. Thus, a VWS would have a significant effect on increasing the life expectancy and decreasing maintenance required for a given section of road.

As an example, a study done in Idaho [4] indicates that overloading on a route that avoided weigh stations averaged 12% above the legal weight. Using fourth power rule as an estimate, the increased pavement damage as a result of this overloading would be 57% greater than for a vehicle with the maximum legal load. The study observed that 32% of the commercial traffic volume on the avoidance route was overloaded, with an overall result that the road damage on this route was approximately 20% higher than originally projected. This means that the road will require more frequent maintenance than if traffic were at the legal limit and the road will reach the end of its projected working life sooner than expected.

EXAMPLE SITES

Saskatchewan – Follow-Up Enforcement

There are three VWS sites in Saskatchewan, located near Prince Albert, Weyburn and Carlyle.

The vehicle images and data are used to identify carriers with "non-compliance tendencies"; carriers that are identified as a potential problem are subject to further enforcement actions (including credential and record checks). To date approximately 60 carriers have been contacted regarding possible violations and the program has been successful in curtailing repeat offences by most of these carriers.

North West Territories – Toll Verification

The VWS site in the Northwest Territories is located just north of the planned Deh Cho Bridge across the Mackenzie River near Fort Providence. The bridge will provide a year round crossing to link Yellowknife and the eastern NWT to southern Canada. The VWS will be used for auditing toll collection on commercial traffic across the bridge (scheduled for completion in the fall of 2010). The records will be used to verify that tolls have been assessed appropriately.

The VWS will also be used to monitor traffic on a 24/7 basis. There is an inspection station that is open 12 hours a day; when this station is closed, the VWS can be used by enforcement officers to monitor traffic. In addition, commercial vehicle data will be analyzed to ascertain traffic patterns and to determine the most effective times to have the weigh station open.

New York - Mobile Screening

The VWS in New York is located at Spring Grove on a four lane divided interstate. The system is a pilot site for comparison of the accuracy and reliability of three different types of Weigh In Motion sensors: Single Load Cell scales, Kistler sensors and Class I Piezoelectric sensors. All three types of sensors are installed in the mainline traffic lane being monitored and data is kept for comparison of the weight of each commercial vehicle among the three sensor types. The WIM sensors are linked to the server electronics by radio communications links. All electronics are powered by solar cells.

The site is used for mobile screening. The mobile screening system typically makes use of a pull-out or rest area downstream from a VWS in which inspection officers set up portable traffic management equipment. When enforcement is to take place, a message sign between the VWS and the pull-out area is activated, directing trucks to report for inspection. The enforcement area includes a mobile office for processing of vehicles and portable scales for enforcement weighing of selected trucks. The mobile screening system provides the ability to cover a larger highway network, flexibility to quickly deploy at a chosen site, and greater efficiency by targeted selection of potential violator vehicles.

An inspection vehicle equipped with a laptop computer and linked to the VWS server is located at a rest stop downstream from the VWS sensors. When inspections are taking place, a report sign on the mainline instructs all trucks to report for inspection. The inspection officers use VWS images of the license plate and DOT number to identify vehicles that the system indicates may be in violation. These vehicles are weighed on portable scales; all other vehicles are visually inspected and allowed to proceed if they are compliant.

Wisconsin – Bypass Monitoring

The Wisconsin VWS systems are used to monitor traffic on two secondary highways that commercial vehicles can use to bypass a static scale inspection station on the interstate highway near Madison, WI (Figure 7 - Wisconsin VWS).

The inspection station is equipped with both mainline and ramp automatic sorting systems that include WIM sensors, AVI readers, imaging cameras and changeable message signs. The virtual weigh stations relay records of vehicles on the bypass highways to the main inspection station, where the enforcement officers view the data and vehicle images and take appropriate action.

CONCLUSION

As truck volumes continue to increase so does the demand for reduced environmental impact and for economic responsibility. Meeting these demands will require more efficient methods for monitoring and managing the use of highway infrastructures to protect both the environment and the investment in infrastructure. Virtual Weigh Stations are a technology that can provide an economical, efficient system for infrastructure management in the areas of data collection, traffic monitoring, commercial vehicle enforcement, toll supervision and a significant reduction in environmental impact.

FIGURES

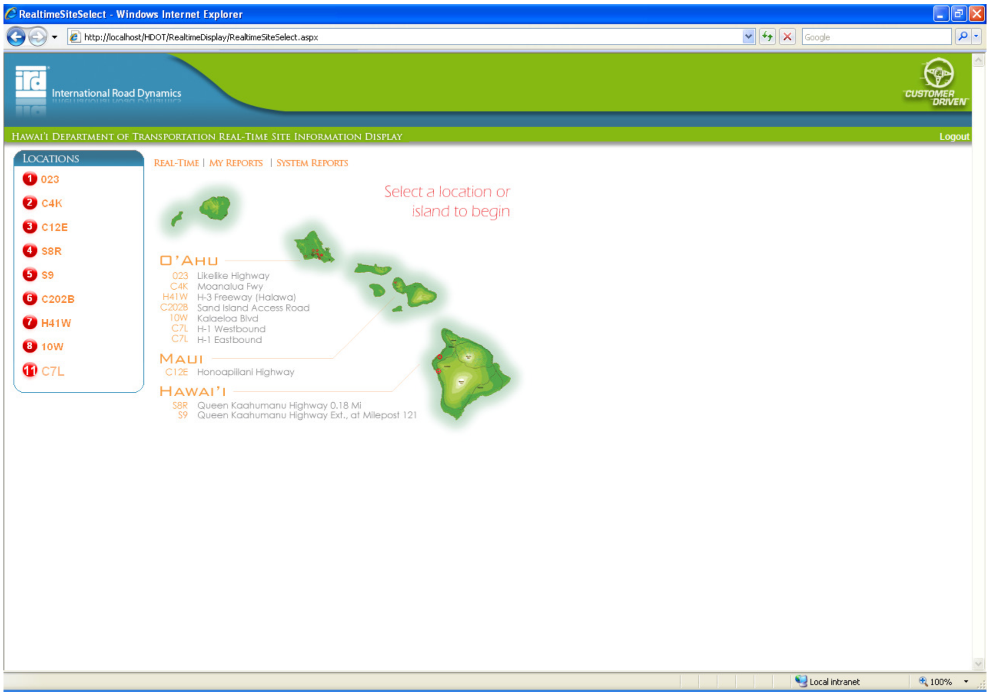


Figure 1 - Multiple VWS Site Map

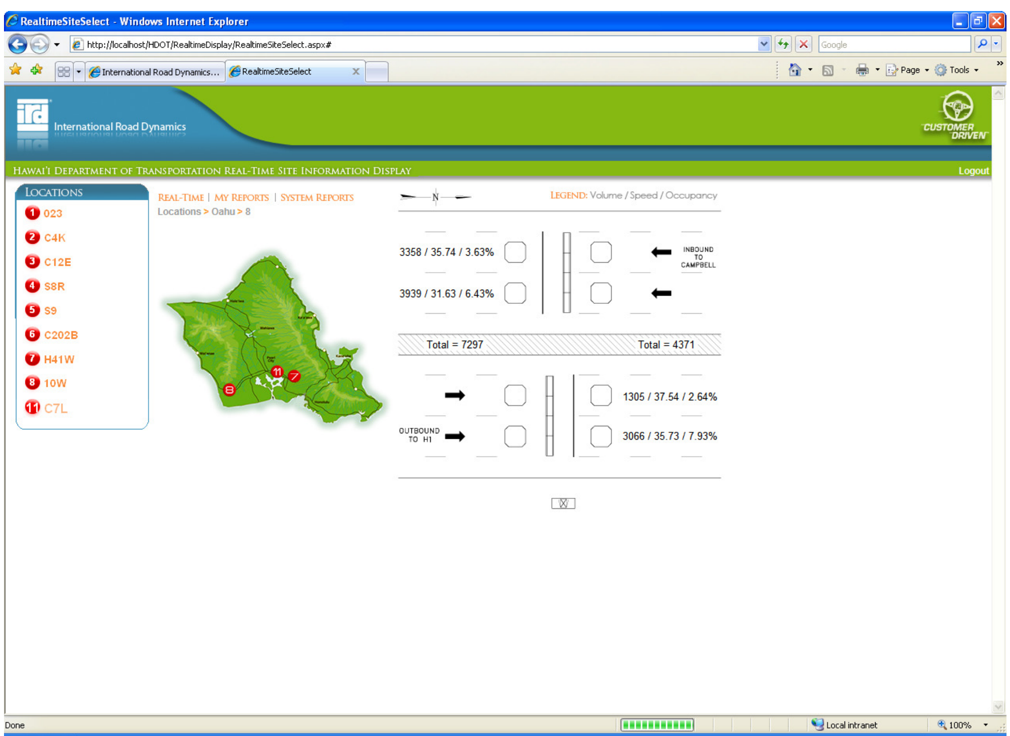


Figure 2 - Regional Site Map

Figure 3 - Virtual Weigh Station Display

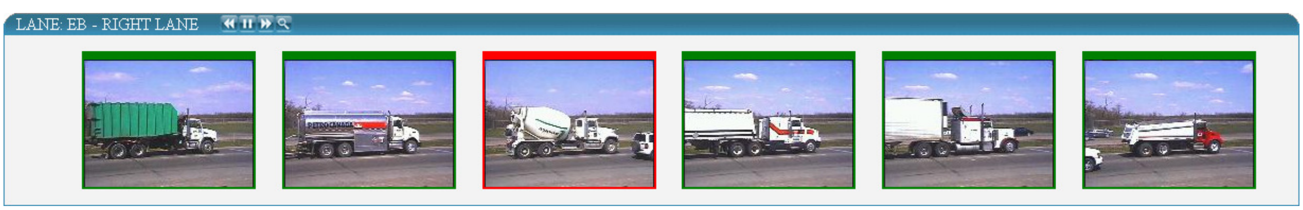
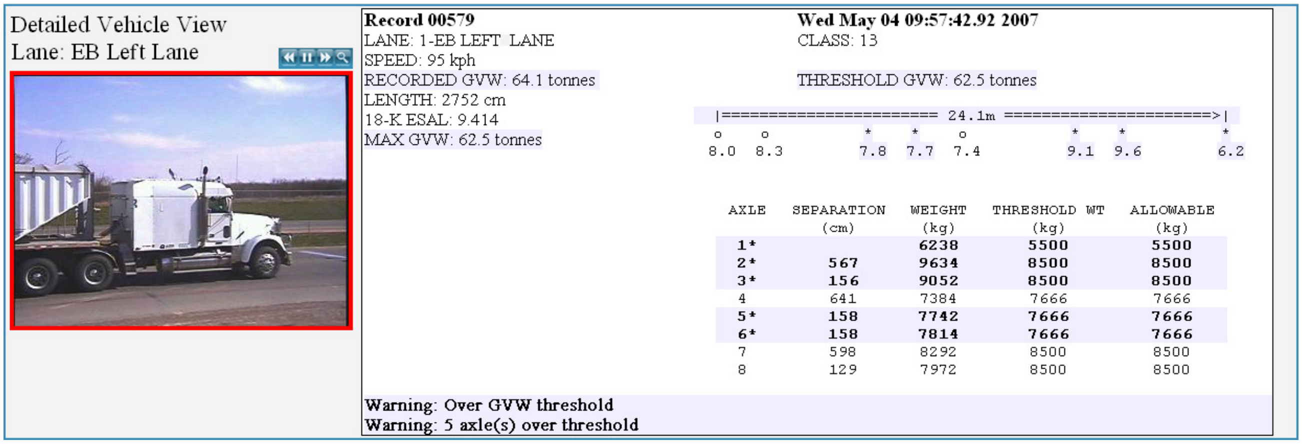


Figure 4 - Lane display



AXLE	SEPARATION (cm)	WEIGHT (kg)	THRESHOLD WT (kg)	ALLOWABLE (kg)
1*		6238	5500	5500
2*	567	9634	8500	8500
3*	156	9052	8500	8500
4	641	7384	7666	7666
5*	158	7742	7666	7666
6*	158	7814	7666	7666
7	598	8292	8500	8500
8	129	7972	8500	8500

Figure 5 - Detailed vehicle record

Figure 6 - Virtual Weigh Station Enclosure and Electronics Rack

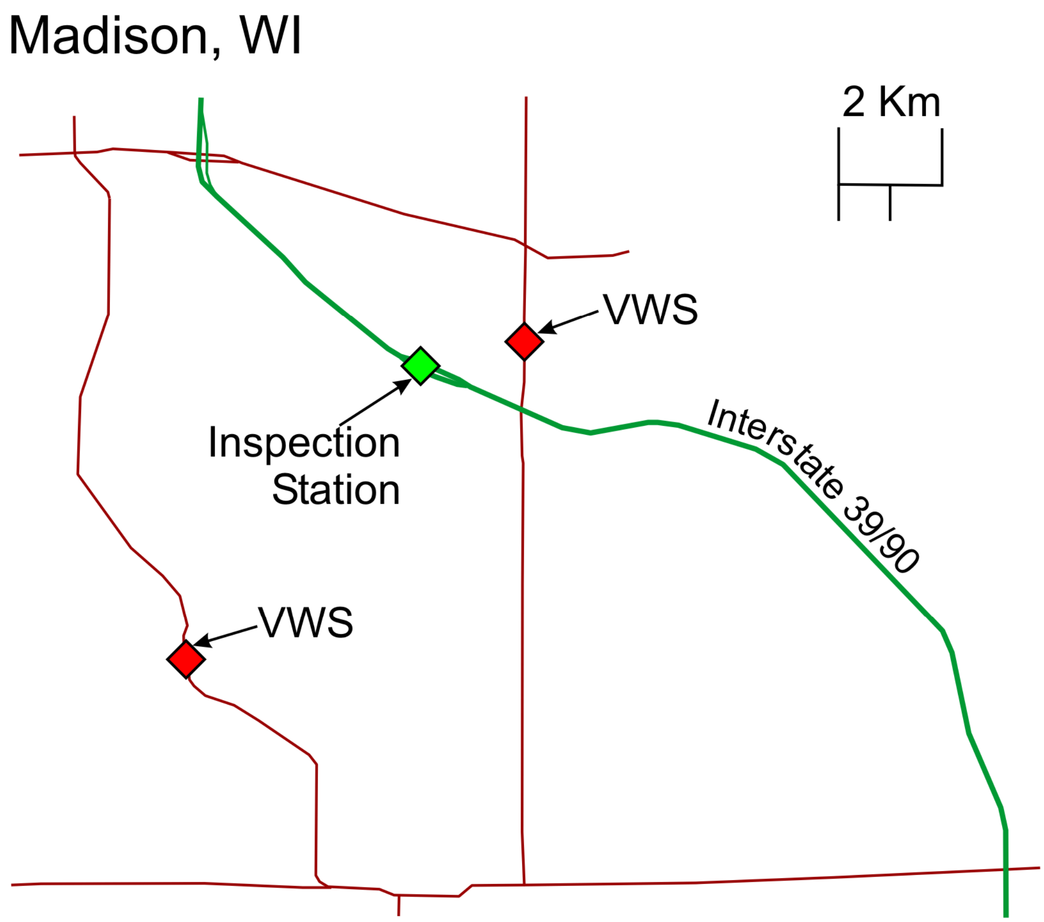


Figure 7 - Wisconsin VWS

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