Study of an Overload Truck Screening System for a Sustainable Highway Bridge network

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1. Introduction

Overloaded vehicles impose great demands on the structural capacity of bridges. Vehicle loading on short and medium bridge spans, the majority of bridges in the United States, are of primary interest. In particular, the combination of heavy axle loads and short axle spacings can cause load effects that may exceed the design capacity of bridges leading to significant deterioration or even collapse. In a recent study of 503 bridge failures from 1989 to 2000, approximately 9% occurred as a result of overloads (Wardhana and Hadipriono 2003).

Although overloaded trucks are of major concern transport by trucks on the nation's network of roads and bridges also significantly contributes to a healthy economy. In 2002, trucks were responsible for shipping nearly 12 billion tons of freight representing almost 60% of all transport activities (FHWA 2007). This number is expected to nearly double by the year 2035. The value of freight shipped by trucks also represents a major portion of the total value of commodities shipped nationwide. In 2002, trucks shipped about $9 trillion of freight which is estimated to increase by 180% in the year 2035 (FHWA 2007).

With an increase in the volume and value of freight shipped by trucks also comes a trend toward heavier and larger truck combinations. From 1987 to 2002, trucks weighing between 100 and 130 kips increased by 238% (FHWA 2007). This observed growth is likely due to several factors including economic growth, technological advances in the freight transportation logistics, and changing trade patterns resulting from the North American Free Trade Agreement (Harwood et al. 2003).

Compounding the problem of an increased volume of heavy truck traffic is the continuing decline of the nation's highway infrastructure. Nearly 25% of the 599,766 bridges nationwide are structurally deficient (SD) or functionally obsolete (FO) (http://www.fhwa.dot.gov/bridge/deficient.htm). In Rhode Island, the number of bridges rated SD/FO is more than double the national average. In November 2007, the Rhode Island Department of Transportation (RIDOT) limited the use of the Pawtucket River Bridge to vehicles weighing less than 22 tons (44 kips) and more recently to 18 tons (36 kips) and 2-axle vehicles. And despite stiff fines imposed by the State, more than 5,600 truckers have been charged with violating the bridge's posted limits resulting in more than $3 million in fines (Providence Journal 2009). This highlights the importance of continued monitoring of the structural integrity of this and other heavily traveled bridges.

The objective of this project is to study the use and implementation of an overload truck screening system for bridge structures among various transportation agencies. This screening system would combine two advanced technologies, namely a weigh-in-motion (WIM) system and a bridge strain sensing system, to detect the passage of overload trucks at highway speeds. A more detailed description of this system is presented in Section 4 of this report.

A review of literature on weigh-in-motion systems as well as a survey of State Departments of Transportation (DOTs) regarding their experiences with both WIM and bridge instrumentation have been conducted. Both are discussed in the sections that follow.

2. Weigh-in-Motion Systems

Truck load information has traditionally been obtained from fixed weigh stations located along major highways often at areas where freight originates or is delivered. Trucks are weighed to check compliance with weight restrictions and are screened by law enforcement personnel to check freight and vehicle paperwork as well as compliance with Hours of Service regulations. However, with the increasing volume of trucks, most weigh stations operate beyond their capacity which creates extensive truck queues, wastes drivers' time and fuel, worsens air pollution, and creates roadway safety hazards. Moreover, many non-complying commercial vehicle drivers alter their travel route to avoid these inspection stations biasing truck load data toward less heavy vehicles (Ghosn and Moses 1986). As a result, many overweight trucks travel undetected causing millions of dollars of damage each year to the highway network.

Weigh-in-motion (WIM) systems, on the other hand, measure truck load information at full highway speeds and without disruption to normal traffic operations (Moses 1979). WIM sensors, typically piezoelectric strip, load cell or bending plate, are directly installed in the roadway surface and are relatively undetectable by roadway users. This results in unbiased truck traffic data (Kim et al. 1996; Laman and Nowak 1997). Consequently, WIM systems have been extensively used by transportation agencies in recent years for monitoring truck loads.

The American Society for Testing and Materials (ASTM) "Standard Specification for Highway Weigh-in-Motion (WIM) Systems with User Requirements and Test Methods" (ASTM E1318-09) classifies WIM systems as Type I, II, III, or IV depending on the type of application and user requirements as shown in Table 2.1. The accuracy of each type of WIM system for its intended function is presented in Table 2.2. The ASTM Standard also specifies user requirements in terms of proper site conditions including horizontal, longitudinal, and lateral (cross-slope) alignment, lane widths and markings, road roughness, and pavement structure as well as calibration and on-site acceptance testing. Table 2.3 presents some of these roadway requirements.

There are different types of WIM sensors including quartz piezoelectric, bending plate, and load cells that may be used. They vary in accuracy, cost, and performance. Table 2.4 presents some cost comparisons of the different WIM sensors including data from the survey of State Departments of Transportation conducted as part of this study.

Table 2. 1 ASTM WIM System Classification (adapted from McCall and Vodrazka 1997 and ASTM E1318-09)

	Type I	Type II	Type III	Type IV[1]
Application	Traffic Data Collection	Traffic Data Collection	Weight Enforcement	Weight Enforcement
Speed Range	10-80 mph	15-80 mph	10-80 mph	2-10 mph
Type of Sensors				
Piezoelectric Sensor	X	X		
Bending Plate	X	X	X	X
Load Cell	X	X	X	X
Vehicle Weight				
Wheel Load	X		X	X
Axle Load	X	X	X	X
Axle-Group Load	X	X	X	X
Gross Vehicle Weight	X	X	X	X
Equivalent Single-Axle Load	X	X		
Vehicle Spacing				
Axle Spacing	X	X	X	X
Wheelbase (front to rear axle)	X	X		
Vehicle Information				
Speed	X	X	X	X
Vehicle Class	X	X		
Lane and Direction of Travel	X	X	X	
Sequential Vehicle Record Number	X	X	X	X
Date and Time of Passage	X	X	X	X
Violation Code	X	X	X	X
Site Information				
Site Identification Code	X	X	X	X

[1] *Not approved in U.S.*

Table 2. 2 Functional Performance Requirements for WIM Systems (ASTM E1318-09)

Function	Tolerance for 95% Compliance				
	Type I	Type II	Type III	Type IV	
				Value ≥ lb	± lb
Wheel Load	± 25%		± 20%	5,000	300
Axle Load	± 20%	± 30%	± 15%	12,000	500
Axle-Group Load	± 15%	± 20%	± 10%	25,000	1,200
Gross Vehicle Weight	± 10%	± 15%	± 6%	60,000	2,500
Speed			± 1mph		
Axle Spacing and Wheelbase			± 0.5 ft		

Table 2. 3 Roadway Characteristic Requirements for WIM systems (ASTM E1318-09)

Road Characteristic[1]	Type I	Type II	Type III	Type IV
Horizontal Alignment	Radius ≥ 5700 ft	Radius ≥ 5700 ft	Radius ≥ 5700 ft	Radius ≥ 5700 ft
Longitudinal Alignment	Slope ≤ 2%	Slope ≤ 2%	Slope ≤ 2%	Slope ≤ 1%
Cross Slope	Slope ≤ 3%	Slope ≤ 3%	Slope ≤ 3%	Slope ≤ 1%
Lane Width	12-14 ft	12-14 ft	12-14 ft	12-14 ft

[1] *For roadway lane 200 ft in advance of and 100 ft beyond the WIM system*

2.1. Quartz Piezoelectric Sensors

Quartz piezoelectric sensors, shown in Figure 2.1, use a quartz sensing element to detect a change in voltage in response to an applied mechanical stress such as a vehicle's axle. The quartz core is housed within a special alloy component surrounded by an elastic material and grouted in place. The sensor is fully embedded in the roadway surface and is held securely in place using epoxy. This means that the load is transferred through the pavement to the sensor and as a result the accuracy of the sensor is affected by the condition of the pavement. Rough or poor pavements create a higher level of inaccuracy and reduce the longevity of the sensors.

The sensor layout typically includes two piezoelectric sensors and two inductive loop detectors (ILD) which detect the presence of vehicle as shown in Figure 2.2. An upstream ILD is used to detect approaching vehicles while an ILD placed downstream is used to determine vehicle speed and axle spacing based on recorded timestamps.

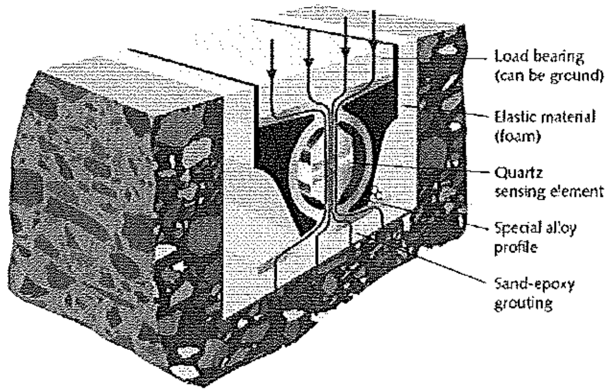

Figure 2. 1 Cross-Sectional view of quartz piezoelectric sensor (Kistler)

Table 2. 4 Cost Comparison of WIM sensors

Category	Source	Piezoelectric	Bending plate	Load cell
Performance (Percent error at highway speeds)	McCall and Vodrazka 1997	± 10%	± 5%	± 3%
	Bushman and Pratt 1998	± 15%	± 10%	± 6%
	Gindy and Tsiatas 2009	-	-	-
Expected life (years)	McCall and Vodrazka 1997	-	-	-
	Bushman and Pratt 1998	4	6	12
	Gindy and Tsiatas 2009	-	-	-
Estimated initial cost per lane[1]	McCall and Vodrazka 1997	$9,500	$18,900	$52,500
	Bushman and Pratt 1998	$9,000	$21,500	$48,700
	Gindy and Tsiatas 2009[3]	$10,000 – $30,000	$35,000 – $40,000	$35,000
Estimated average cost over 12-year lifespan[2]	McCall and Vodrazka 1997	$4,224	$4,990	$7,296
	Bushman and Pratt 1998	$4,750	$6,400	$8,300
	Gindy and Tsiatas 2009[3]	$2,000 – $5,000	$4,000 – $4,500	$3,500

[1] *Initial costs only include equipment and installation costs. The cost of the electronics, cabinet, power supply, telephone connection, and roadway preparation are assumed constant among the three WIM sensor types and are not included.*
[2] *This includes costs of semi-annual maintenance (without the cost of a calibration vehicle).*
[3] *Only one state (Oregon) reported using load cells*

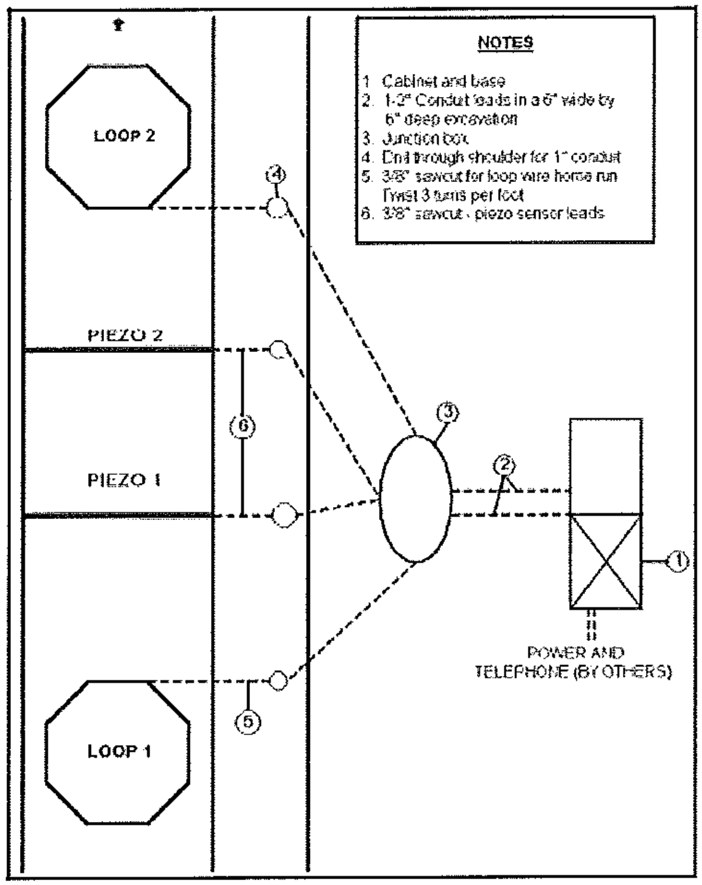

Figure 2. 2 Example of Sensor Layout using Piezoelectric Sensors (McCall and Vodrazka 1997)

2.2. Bending Plate Sensors

Bending plates, shown in Figure 2.3, are steel weigh pads that use strain gauge weighing elements attached to the underside to detect and weigh wheel loads. The sensor layout includes two bending plates, two inductive loop detectors and an axle sensor to measure vehicle length and axle spacing as shown in Figure 2.4. The bending plates are typically 2ft. by 6ft. adjacently placed to cover a 12ft lane width.

If installed in concrete roadways, a shallow excavation is made in the roadway surface and the plates are secured with anchors and epoxy. If installed in asphalt or thin concrete roads, a 5ft by 14 ft concrete vault approximately 30" deep is required to form a secure foundation prior to installation. Bending plates are considered scale-type WIM sensors and are less affected by the condition of the pavement. This results in a longer lifespan and higher accuracy when compared to Quartz Piezoelectric sensors.

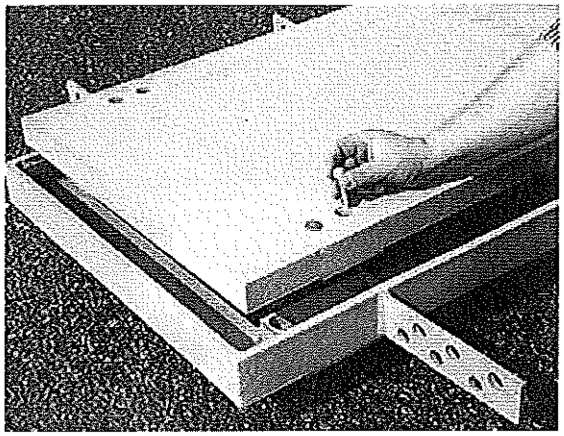

Figure 2. 3 Bending plate sensor (International Road Dynamics)

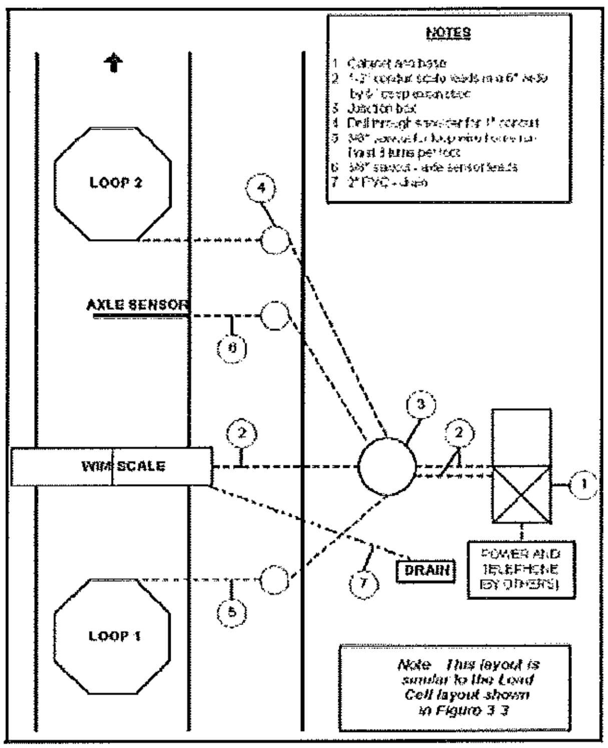

Figure 2. 4 Example of Sensor Layout using Bending Plate System (McCall and Vodrazka 1997)

2.3. Single Load Cell Sensor

A single load cell WIM system consists of one load cell with two weigh pads to record both right and left axle weights simultaneously as shown in Figure 2.5. As with the bending plate system, the single load cell sensor layout includes two ILD and an axle sensor. A concrete vault is also required for installation in both concrete and asphalt roadways. Load cells can achieve an ASTM Type III level of accuracy (GVW ± 6%) and have a much longer lifespan of 12 years. This improved overall quality results in a much higher cost than the previous two systems. Initial equipment and installation costs are approximately $50,000 with an average annual life cycle cost of about $8,000.

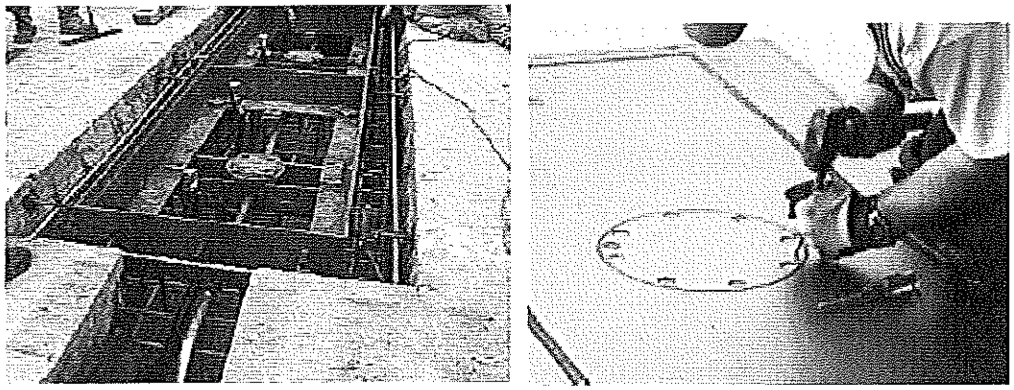

Figure 2. 5 Single Load Cell WIM System (International Road Dynamics)

3. Survey of State Departments of Transportation

A survey of State Departments of Transportation (DOTs) regarding their use and experience with WIM systems and bridge instrumentation practices was performed. The survey contained two parts; Part I pertained to truck load information and Part II pertained to bridge instrumentation practices. The survey was sent to nearly all 50 states yet only eleven surveys were returned. Of the eleven, four states have either not installed any WIM sensors or used bridge instrumentation for the purpose of monitoring overloads. A summary of the survey results from the remaining seven states is provided below. Appendix A contains survey responses as they were received.

3.1. Part I: Truck Load Information

This first part sought responses concerning the number and type of WIM sensors maintained, experience with WIM systems, cost information, data retrieval and handling, system calibration and data quality assurance practices, and data integration into a GIS system.

There was a considerable range in the number of WIM systems managed by the different states ranging from 4 (Connecticut) to 104 (South Carolina). Most states exclusively use permanent WIM systems defined as those where both the sensors and data collection equipment collect data at the same location. Two others (Nevada and South Carolina) also use portable WIM systems where both sensors and data collection equipment are moved from site to site and one (Oregon) uses semi-permanent systems where the sensors are built into the pavement while the data collection equipment is moved from site to site. When asked about their experience with portable WIM systems, most states report some setbacks including tedious calibration and difficulty of collecting accurate data due to calibration limitations.

The most common type of WIM system was reported to be the quartz piezoelectric system. Only two states use the bending plate system and one (Oregon) uses load cells.

The cost of WIM systems was broken down to initial cost per lane and the average cost over a 10-year period. In general, the quartz piezoelectric system was the least expensive with an initial cost ranging between $10,000 and $30,000 and an average annual cost of $2,000 to $5,000 per lane. The bending plate system was reported to have an initial cost of $35,000-$40,000 and an average annual cost of $4,000-$4,500. The load cell system was reported to have similar costs ($35,000 initial cost and $4,000 annual cost).

Nearly all states employ an automated process for daily retrieval of data using telemetry. Most reported collecting WIM data for use in pavement design and maintenance as part of the Long-Term Pavement Performance (LTPP) Program. Other uses include weight enforcement, development and application of equitable tax structures, projecting future traffic patterns and highway road design. Most states listed vehicle classification, gross vehicle weights and individual axle weights and spacings as the most valuable data collected followed by equivalent single axle load (ESAL) values, vehicle speed, lane of travel, and total volume.

When questioned about system calibration and data quality assurance practices, most states reported using the ASTM E1318-09 Standard Specification for Highway WIM Systems or the LTPP field guidelines for field validation to initially calibrate WIM systems. The frequency of calibration of permanent WIM systems greatly varied among states. Some reported field calibration on an as needed basis or when problems arose to twice per year. All states except one also reported having a quality assurance program. The specifics varied between states but most checked some traffic characteristics (i.e. volume by class) to historical data from the same site. Other checks reported include vehicle speed, gross and axle weights and spacings, wheelbase, left/right axle weight imbalance, number of errors or unclassified vehicles, and hours of zero volume.

Finally, when asked about whether their WIM data was integrated into a GIS-based system, the response was split nearly 50-50. This may perhaps indicate a shift in how WIM data is currently being handled.

3.2. Part II: Bridge Instrumentation Practices

The second part of the survey to State DOTs centered on bridge instrumentation practices particularly those used for overload detection. All states reported using non-destructive testing methods as part of bridge inspection practices. Some of the methods reported were dye penetrant inspection (DPI) or liquid penetrant inspection (LPI), ultrasonic testing (UT), magnetic particles, ground penetrating radar (GPR), strain gauges, load testing, and displacement sensors. When questioned specifically on whether or not instrumentation is used to assess the effects of overloads on bridges, the response was exactly 50-50. The four states that use instrumentation for this purpose reported instrumenting between one to six bridges each year with strain gauges, linear variable differential transducers (LVDTs), and acoustic emission testing. One state (Oregon) reported instrumenting ten bridges with permanent structural health monitoring systems.

Typical tests include diagnostic static and dynamic load tests with normal truck traffic and test vehicles of known weight and configuration. Most states also reported collaborating with a local University for performing such tests.

When questioned about whether or not bridge instrumentation is linked with a WIM system for the purpose of monitoring the effects of overloads, nearly all states responded negatively. Only one state (Connecticut) has linked a bridge strain sensing system with a WIM system to provide real-time data on the effects of overloads.

4. Proposed Overload Truck Screening System

With the detailed description of weigh-in-motion (WIM) systems and bridge instrumentation practices of different States provided above, an overload truck screening system is now proposed. This system will dynamically link a WIM system with a bridge strain sensing system on a selected bridge as shown in Figure 4.1.

In general, truck traffic information is recorded using the WIM installed at the entrance of the bridge. As the truck travels over the bridge, strain sensors installed at a targeted location (i.e. maximum stress location) along a bridge girder simultaneously records strain. If the strain level imposed by the truck exceeds a predefined safe threshold level, the integrated system is triggered. Once a loading event is flagged, the girder response along with the detailed truck information such as time of travel, travel lane, type of truck, vehicle speed, total weight, and individual axle weights and spacings are recorded. This database can be accessed and analyzed by bridge owners at any time. The data can provide insight into a number of important factors including the frequency and extent of overloading, effect of continued overloading, characteristics of trucks that are likely to cause overstressing, and time of day such trucks are likely to travel the selected bridge.

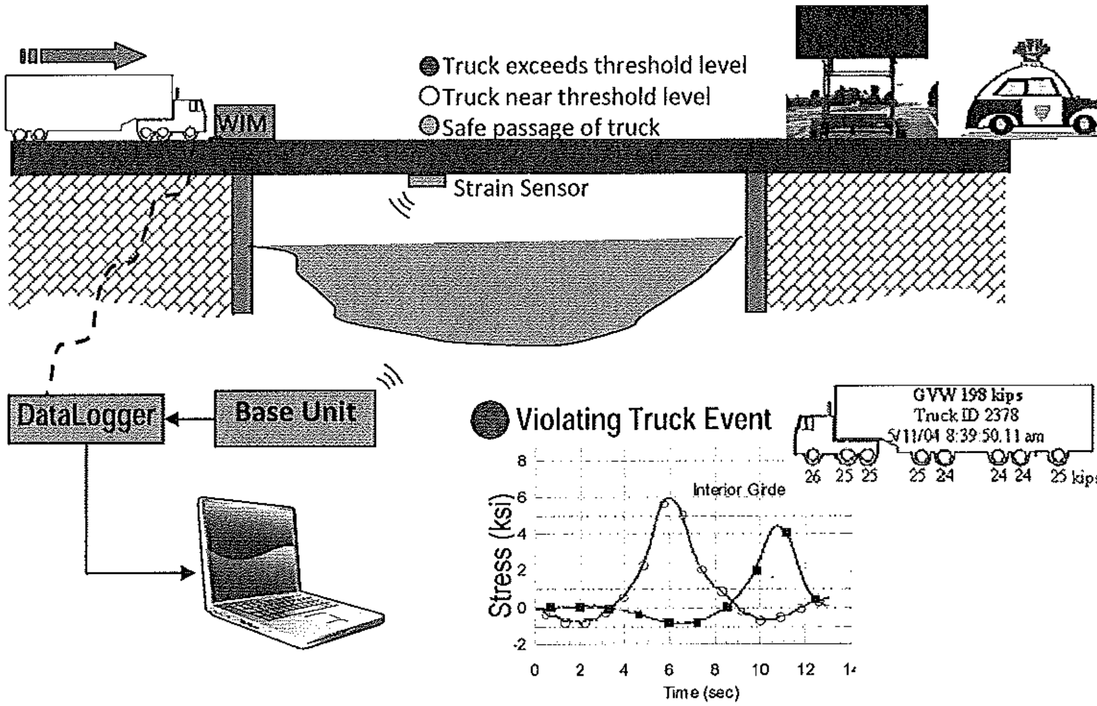

Figure 4. 1 Schematic of Overload Truck Screening System

5. Conclusions

As the volume of heavy trucks increases and the condition of the nation's roadway network worsens, many State Departments of Transportation are left with a real problem; how to assess and monitor the condition of heavily traveled bridges due to truck overloads. Instrumentation offers one solution. Sensors can offer a tremendous amount of information and when combined in an integrated system as the one proposed herein, sensors can provide just the right amount of useful information.

Perhaps a good way of highlighting the benefits of bridge instrumentation is to quote the Oregon State Department of Transportation from their survey response; "The first bridge tested usually more than pays for the equipment cost. It is extremely effective for gathering information to make informed decisions concerning load restrictions, repairs or bridge replacement".

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Appendix A

Responses from State Departments of Transportation

State **Part I: Truck Load Information**

How many weigh-in-motion (WIM) sites do you manage?

State	Permanent	Semi-permanent	Portable
Connecticut	4	0	0
Florida	36	0	0
Iowa	-	-	-
Nevada	8	0	25
Oregon	21	21	0
Pennsylvania	13	0	0
South Carolina	14	0	90
Utah	7	0	0

What type of WIM systems do you have?

State	Piezoelectric WIM Systems	Bending Plate WIM Systems	Load Cell WIM Systems	Other
Connecticut	-	-	-	Quartz-Piezoelectric
Florida	X	X	-	Quartz-Piezoelectric
Iowa	-	-	-	-
Nevada	X	X	-	Kistler Lineas Quartz Sensor
Oregon	-	-	X	-
Pennsylvania	-	-	-	Quartz-Piezoelectric
South Carolina	X	-	-	-
Utah	X	-	-	-

What manufacturer do you use? (Enter the number of WIM sites from each manufacturer)

State	International Road Dynamics	Massload	Mettler Toledo	Other
Connecticut	X			
Florida	36			
Iowa	-	-	-	
Nevada	X			
Oregon	X			
Pennsylvania	X			
South Carolina				PEAK/Measurement Specialites
Utah				Cardinal

	How long have you maintained a WIM program?
Connecticut	No Response
Florida	35 years
Iowa	-
Nevada	31 years
Oregon	12 years
Pennsylvania	20 years
South Carolina	20 years
Utah	15 years

	What is your experience with operating and installing permanent WIM systems?
Connecticut	Experience over the last 20 years conducting WIM research and installation and data collection for the Long-Term Pavement Performance Program.
Florida	We've done it all--from personally installing the systems, to calibrating them, to operating them, downloading and processing data.
Iowa	-
Nevada	We have 14 years of expierence with installing permanent WIM systems, most of our sites were put in on contracts with the exception of one site with piezoelectric type sensors which we installed with the supervision from International Road Dynamics IRD/PAT. We oversee all the installations, calibrations and acceptance of the WIM systems and plan on installing two more sites with piezoelectric type sensors in the next two years.
Oregon	Design/Layout, Technical drawings, budget-estimates, contract administration, construction oversight, acceptance testing, full in-road and system electronics maintenance. We currently have a unit within our division that handles all aspects of our WIM program. Our WIM systems are in conjuction with Oregon's size and weight program.
Pennsylvania	Data collection by DOT, Maintwnance by contract.
South Carolina	Contractor installs permanent WIM with oversight from our inhouse Equipment Expert. Numerous calibration issues, sensor sentivity, and pavement deterioration make it difficult to maintain and collect accurate data.
Utah	This process has always been accomplished using contractors.

	What is your experience with portable WIM systems?
Connecticut	ConnDOT planning used a portable system for many years.
Florida	We experimented with capacitance mats in an attempt to get project-specific WIM data, but were unhappy with the results.
Iowa	-
Nevada	We currently collect portable WIM data using Series Eight CAP MATS and PAT DAW190P recorder but are phasing them out due to the cost of collecting the data compare to the amount of data collected, accuracy level of data and the inability to have the equipment serviced.
Oregon	N/A
Pennsylvania	None
South Carolina	SCDOT inhouse technicians do our own setup and collection of portable WIM systems. Setup and calibration can be tedious. Sometimes it is also difficult to collect accurate data due to limitations on calibration.
Utah	We tried portable WIM for several years and found that it was not successful. We have discountinued the program.

What is the estimated initial cost per lane for each system?

	Piezoelectric WIM Systems	Bending Plate WIM Systems	Load Cell WIM Systems	Other
Connecticut				Q-WIM $12,000
Florida	$20,000	$40,000		Q-WIM $30,000
Iowa	-	-	-	-
Nevada	$15,000	$35,000		Lineas Quartz Systems, $25,000
Oregon			$35,000	
Pennsylvania				Quartz, $30,000
South Carolina	10,000			
Utah				We use PREPASS, the state is not charged for initial setup

What is the estimated average cost per lane over a 10-yr life span including maintenance

	Piezoelectric WIM Systems	Bending Plate WIM Systems	Load Cell WIM Systems	Other
Connecticut	-	-	-	-
Florida	$50,000	$40,000		Q-WIM $30,000
Iowa	-	-	-	-
Nevada	$25,000	$45,000		Lineas Quartz Systems, $35,000
Oregon			$40,000	
Pennsylvania				Quartz, $20,000
South Carolina	20,000			
Utah	-	-	-	-

How do you retrieve WIM data?

	Telemetry	On-site download	Other
Connecticut	X	X	
Florida	X		
Iowa	-	-	
Nevada	X	X	
Oregon	X		
Pennsylvania	X		
South Carolina	X	X	
Utah	X		

	How often do you retrieve WIM data?
Connecticut	Bi-weekly
Florida	Nightly
Iowa	-
Nevada	Daily
Oregon	Daily
Pennsylvania	Daily
South Carolina	Nightly for permanent sites - and for portable, as collected for 48 hour collecction
Utah	Live Feed

	Do you have an automated process for downloading WIM data?	
	Yes	No
Connecticut		X
Florida	X	
Iowa	-	-
Nevada	X	
Oregon	X	
Pennsylvania	X	
South Carolina	X	
Utah	X	

	For what purpose do you use the WIM data?
Connecticut	Pavement design, research, traffic monitoring for LTPP
Florida	Pavement design.
Iowa	-
Nevada	Pavement design and maintenance, weight enforcement, development and application of equitable tax structures and Federal submittal of weight, count and classification data to the Federal Highway Administration.
Oregon	traffic volume tables, i,e vehicle volume, vehicle classification, vehicle weight, peak traffic patterns, projecting future traffic patterns, highway road design.
Pennsylvania	Federal reporting and DOT research
South Carolina	For Federal Submission and provided data to the Transport Police
Utah	Screening commercial vehicles for regulatory purposes.

Which data do you find most valuable? (Check all that apply)

	Vehicle classification	Gross vehicle weights	Individual axle weights and spacings	ESAL values	Vehicle speed	Lane of Travel	Other
Connecticut	X	X	X		X	X	
Florida	X	X	X	X	X		
Iowa	-	-	-	-	-	-	
Nevada	X	X	X	X	X		
Oregon	X	X	X	X			Total Volume
Pennsylvania	X						
South Carolina	X	X	X	X	X		
Utah	X	X	X				

Describe your initial system calibration procedure:

	Per ASTM 1318-09 Standard Specification for Highway WIM Systems	Modification of ASTM 1318-09 Specifications. Please describe:	Other. Please describe
Connecticut		Use LTPP field guidelines for field validation	
Florida		We only use class 09 trucks with air-ride suspensions, loaded to 70,000 - 80,000 pounds GVW. I'm more interested in accurately weighing loaded trucks than I am in weighing empty trucks.	
Iowa	-	-	-
Nevada	X		
Oregon	X		
Pennsylvania			Automatic by software.
South Carolina	X		
Utah			Every 100th truck the system automatically pulls the vehicle onto the scale the truck is scaled and averaged . The system is calibrated based on that information.

	How often do you field calibrate each permanent WIM system post-installation?
Connecticut	No Response
Florida	As needed. Around once every 4-5 years for bending plate and quartz sensor systems.
Iowa	-
Nevada	Triennially, unless data drifts occur or when major repairs to the system are required
Oregon	As needed, but at least quarterly
Pennsylvania	2 per year
South Carolina	When problems arise or on occasion
Utah	PREPASS performs this function

	Describe your in-service field calibration procedure:
Connecticut	FHWA - LTPP filed guidelines for calibration/validation
Florida	We calibrate to a class 9 truck with air-ride suspension on the tractor and trailer. We usually make around 18 - 25 passes at 5MPH increments distributed around the normal highway speed the trucks on the highway are running.
Iowa	-
Nevada	Calibration /verification procedures are performed using a fully loaded class 09 type vehicle (3S2) weighed with certified scales making ten passes in each lane at three different predetermined speeds.
Oregon	20-truck sample from normal flow of traffic, compared to static weighings
Pennsylvania	10 passes with loaded class 9 - 95% accuracy
South Carolina	calibration with a know weight
Utah	N/A

	What is your experience with field calibration of WIM systems?
Connecticut	Experience from 1990-2005 using trucks of known weight similar to LTPP field data collection
Florida	If the pavement is smooth, and the equipment is in good working order, the WIM systems can be calibrated within a day, as long as the truck doesn't have to drive long distances between turn around points.
Iowa	-
Nevada	NDOT calibrates, maintains and repairs all of our permanent WIM systems.
Oregon	See above
Pennsylvania	Quartz sensors are extremely reliable - we are changing calibrations to 1 per year
South Carolina	We have done field calibration for 20 years
Utah	N/A

Do you have a quality assurance (QA) program?

	Yes	No	Describe
Connecticut	X		The data is reviewed for specific criteria at the state level and is checked by the FHWA-LTPP Regional contractor using the QC?LTPP
Florida	X		Automated reports of each lane showing the number of truck records passing edits of vehicle class, speed, gross and axle weights, axle spacings, wheelbase and gross lengths, and left/right imbalance. Manual monthly plots of class 09 GVW distributions compared to historical data at the same site.
Iowa	-	-	-
Nevada	X		We use TRADAS software by Chaparrel Systems Corporation to process our data which checks the count data for missing hours of data, the vehicle classs data for zero hours of trucks by lane, gross weight distribution graphs which show drifts in calibrtion, overwight reports by day, unclassified reports , ESAL reports and vehicle classifiction reports are used to validate the data.
Oregon	X		daily monitoring
Pennsylvania		X	
South Carolina	X		data integrity checks are performed by analysts
Utah	-	-	-

Do you use autocalibration (post-collection data editing)?

	Yes	No
Connecticut		X
Florida		X
Iowa	-	-
Nevada		X
Oregon		X
Pennsylvania		X
South Carolina	X	
Utah	-	-

What checks are used to assess the collection of quality data?

	Number of unclassified vehicles	Number of Class 1 (motorcycles) counts	Frequency by vehicle class	Vehicle speed	Distribution of GVW of class 9 vehicles	Front axle weight shifts by vehicle class	Vehicle lengths by class	Percentage of overweight vehicles	Other:
Connecticut	X				X	X			Number of errors and number of unclassified vehicles
Florida	-	-	-	-	-	-	-	-	-
Iowa	-	-	-	-	-	-	-	-	-
Nevada	X	X	X		X		X		
Oregon	X		X	X	X	X	X	X	
Pennsylvania	-	-	-	-	-	-	-	-	-
South Carolina			X	X	X		X	X	
Utah					X				

Is your WIM data integrated into a GIS-based system?

	Yes	No
Connecticut		X
Florida		X
Iowa	-	-
Nevada		X
Oregon	X	
Pennsylvania	X	
South Carolina		X
Utah	X	

State **Part II: Truck Load Information**

Do you use non-destructive methods as part of bridge inspection practices?

State	Yes	No	Methods
Connecticut	X		A wide variety
Florida	X		On an as needed bases, dye penetrant and magnetic particle by the bridge inspection crew. Other NDT methods that require specially trained personnel are contracted on rare occaisons as determined to be needed.
Iowa	X		Crack detection methods such as UT and Magnetic particles
Nevada	X		Ultrasonics, magnetic particle, dye penetrant, eddy current, and GPR.
Oregon	X		VT,MT,PT,UT,AE and general instrumentation using strain gages and displacement sensors. Thermal imaginging is also used on occation.
Pennsylvania	X		Primarily dye penetrant and sometimes ultrasonic testing
South Carolina	X		Dye penetrant, mag. particle, ultrasonic, load testing, health monitoring
Utah	X		Visual inspection program.

Do you use instrumentation for assessing the effects of overloads on bridges?

State	Yes	No
Connecticut	X	
Florida		X
Iowa	X	
Nevada		X
Oregon	X	
Pennsylvania	X	
South Carolina		X
Utah		X

	On average, how many bridge instrumentation projects do you have per year?
Connecticut	1
Florida	0, for overloads
Iowa	1
Nevada	N/A
Oregon	6
Pennsylvania	1 to 2
South Carolina	Varies
Utah	N/A

	What types of instrumentation have you used?
Connecticut	Strain - primarily
Florida	N/A
Iowa	BDI system
Nevada	N/A
Oregon	Somat Edaq, Vallen acoustic emission testing system. We also have 10 bridges with permenant structural health monitoring systems installed that down load date to a central computer servers for analysis.
Pennsylvania	Typical strain gages and LVDTs. We have also usedLifeSpan Technologies' Model LST Structural Health Sensor (LST) and Matech Material Technologies' Electrochemical Fatigue Sensor (EFS) systems
South Carolina	BDI and LifeSpan Technologies sensors
Utah	N/A

	What types of tests are performed?
Connecticut	Test vehicles and normal traffic
Florida	N/A
Iowa	Diagnostic load test using BDI system
Nevada	N/A
Oregon	Mostly calibrated load testing as well as quantifying service stress ranges
Pennsylvania	Typically we perform static load tests, crawl speed tests, and short term monitoring of normal traffic.
South Carolina	static and dynamic
Utah	N/A

	Who performs these tests?
Connecticut	ConnDOT & UCONN
Florida	N/A
Iowa	Iowa State University
Nevada	N/A
Oregon	Engineers
Pennsylvania	We contract with a consultanting firm who then typically contracts with a university such as Lehigh University.
South Carolina	Clemson University, SCDOT and LifeSpan Technologies
Utah	N/A

Have you linked bridge response sensors to a WIM system

	Yes	No	Describe
Connecticut	X		Multiple strain gages
Florida		X	
Iowa		X	
Nevada		X	
Oregon		X	
Pennsylvania		X	
South Carolina		X	
Utah		X	

	What benefits and drawbacks have you experienced with this system?
Connecticut	Non-destructive evaluation of truck loads
Florida	N/A
Iowa	N/A
Nevada	N/A
Oregon	N/A
Pennsylvania	N/A
South Carolina	N/A
Utah	N/A

	Does the system provide real-time data?
Connecticut	Yes
Florida	N/A
Iowa	N/A
Nevada	N/A
Oregon	N/A
Pennsylvania	N/A
South Carolina	N/A
Utah	N/A

	Have you used this system for enforcement efforts?
Connecticut	No
Florida	N/A
Iowa	N/A
Nevada	N/A
Oregon	N/A
Pennsylvania	N/A
South Carolina	N/A
Utah	N/A

	Have you had any long-term bridge monitoring projects (last 5 yrs)?
Connecticut	Yes
Florida	Yes
Iowa	No
Nevada	No
Oregon	Yes
Pennsylvania	No
South Carolina	Yes
Utah	No

	What is your experience with instrumenting bridges for condition assessment?
Connecticut	Extensive
Florida	We currently have long term monitoring on several bridges for scour and to monitor cathodic protection systems. We have just initiated a research project to monitor 1 bridge superstructure for stress and 2 substructures to monitor resistance of the water to detrmine the proper sacrificial material as part of a cathodic protection system.
Iowa	Only used to remove or reduce load posting . Visit this link for more information: http://www.iowadot.gov/bridge/research.htm
Nevada	None, to date.
Oregon	The first bridge tested usually more then pays for the equipment cost. It is extremely effective for gathering information to make informed decessions concerning load restrictions, repairs or bridge replacement.
Pennsylvania	The purpose of instrumentation and monitoring of a bridge is to diagnose a known deficiency and to develop retrofit details to correct the deficiency. We do not monitor a bridge for condition assessment with respect to an inspection assessment.
South Carolina	We have just started
Utah	N/A