Texas A&M Transportation Institute | TRANSPORTATION Policy Research CENTER

Intelligent Freight Monitoring: A Review of Potential Technologies

Heavy commercial motor vehicles (CMVs) that operate illegally by being oversize or overweight damage transportation infrastructures such as pavements and bridges, and can be hazardous to the safety of the traveling public (*1*, *2*) (Figure 1). This desktop review study, evaluated potential applications of new technologies to advance the development of an intelligent traffic and freight monitoring system. Such a system can help transportation and law enforcement agencies remotely monitor where, when, and how heavy vehicles operate on the road network.

Pavement damage by tanker trucks in Dewitt County, Texas (*2*)

Pavement damage in Karnes County, Texas (*2*)

Highway 183 underpass over Loop 12 in Irving, Texas, damaged by an oversize tractor December 2014 (*3*)

Figure 1. Pavement and Bridge Damage due to Overweight and Oversize Vehicles.

The purpose of this study was to review the existing literature and resources to identify technological systems that have potential applications in efficiently monitoring and regulating freight movement in Texas. In this literature review, researchers identified eight technology categories. Researchers then evaluated and compared various technological systems under these eight categories based on the literature available for these products. These eight technology categories can be divided into two broad groups:

- **Technologies directly implementable by state agencies** (e.g., the Texas Department of Transportation [TxDOT] and the Department of Public Safety [DPS]). These technologies can be directly implemented without any direct industry participation. That is, the users (the trucking industry) are not required to install any systems or devices in their vehicles for the technology to operate. Technology categories in this group include:
    - Virtual weigh-in-motion (WIM) stations.
    - Portable WIM systems.
    - Portable scales.
    - Bridge collision avoidance technologies.

- **Self-regulation or self-enforcement technologies.** Implementation of technologies in this category for enforcement purposes requires industry participation, through installation of certain device(s) in their vehicles or at their loading facilities. From a policy perspective, these technologies may not be immediately implementable as far as the transportation agencies are concerned. However, these technologies have clear benefits to the trucking industry in terms of reducing time spent at weigh stations and can be useful for enforcing weight regulations if industry participation can be ensured. Therefore, researchers reviewed these technologies and include them in this policy brief. Technology categories in this group include:
    - Remote measurement of axle weights.
    - Vehicle telematics.
    - Permits with tracking codes.
    - Certified scales for self-weight.

Researchers reviewed existing studies, articles, and associated publications where available, and performed an Internet search for each technology category. The findings are summarized in this policy brief. However, very few independent studies are available with objective comparisons of these technologies. Therefore, product information provided by the vendors/suppliers served as the primary source of information for comparing the technologies in this study. The manufacturers of the technological systems and their authorized suppliers were also contacted to get detailed information and price estimates for each system.

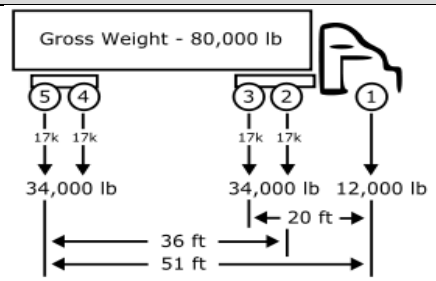
In addition to reviewing technologies for monitoring overweight vehicle loads and movements, the researchers identified the safety hazard posed by oversize (over-height) vehicles to low-clearance bridges as a relevant and pressing issue. Therefore, a review of potential bridge collision avoidance technologies was also included in the study.

Oversize/Overweight Enforcement: Current Regulations and Practices

To provide safe, effective, and efficient movement of people and goods, the Texas Legislature and TxDOT established size and weight limits for vehicles and loads moving on Texas roadways and bridges (*4*). Table 1 gives a summary of these size and weight limits.

In addition to these state limits, the federal bridge formula determines acceptable weight limits on interstate highways (*4*). The bridge formula defines a range of permissible gross loads for vehicles in regular operation on interstate highways; Table 2 shows these permissible truck weight limits.

Table 1. Texas Permissible Truck Size and Weight Limits.

Item/Description	Limits	Graphics
Weight		
Gross vehicle weight (GVW)	80,000 lb	
Steering (front) axle Single axle	12,000 lb 20,000 lb	
Tandem axle group	34,000 lb	
Tridem axle group	42,000 lb	
Quad axle group	50,000 lb	
Size		
Width	8.5 ft (8 ft 6 inches)	
Height	14.0 ft (14 ft 0 inches)	
Length		
Single-motor vehicle	45.0 ft (45 ft 0 inches)	
Truck-tractor	Unlimited	
Semitrailer, of two vehicle combination	59.0 ft (59 ft 0 inches)	
Two- or three-vehicle combination	65.0 ft (65 ft 0 inches)	

Source: (*4*)

Table 2. Federal Permissible Gross Loads for Vehicles: Bridge Formula Table.

Distance in feet between the extremes of any group of 2 or more consecutive axles	Maximum load in pounds carried on any group of 2 or more consecutive axles*							
	2 axles	3 axles	4 axles	5 axles	6 axles	7 axles	8 axles	9 axles
4	†34,000							
5	†34,000							
6	†34,000							
7	†34,000							
8 and less	†34,000	34,000						
more than 8	38,000	42,000						
9	39,000	42,500						
10	40,000	43,500						
11		44,000						
12		45,000	50,000					
13		45,000	50,500					
14		46,500	51,500					
15		47,000	52,000					
16		48,000	52,500	58,000				
17		48,500	53,500	58,500				
18		49,500	54,000	59,000				
19		50,500	54,500	60,000				
20		51,000	55,500	60,500	66,000			
21		51,500	56,000	61,000	66,500			
22		52,500	56,500	61,500	67,000			
23		53,000	57,500	62,500	68,000			
24		54,000	58,000	63,000	68,500	74,000		
25		54,500	58,500	63,500	69,000	74,500		
26		55,500	59,500	64,000	69,500	75,000		
27		56,000	60,000	65,000	70,000	75,500		
28		57,000	60,500	65,500	71,000	76,500	82,000	
29		57,500	61,500	66,000	71,500	77,000	82,500	
30		58,500	62,000	66,500	72,000	77,500	83,000	
31		59,000	62,500	67,500	72,500	78,000	83,500	
32		60,000	63,500	68,000	73,000	78,500	84,500	90,000
33			64,000	68,500	74,000	79,000	85,000	90,500
34			64,500	69,000	74,500	80,000	85,500	91,000
35			65,500	70,000	75,000	80,500	86,000	91,500
36			‡ 66,000	70,500	75,500	81,000	86,500	92,000
37			‡ 66,500	71,000	76,000	81,500	87,000	93,000
38			‡ 67,500	71,500	77,000	82,000	87,500	93,500
39			68,000	72,500	77,500	82,500	88,500	94,000
40			68,500	73,000	78,000	83,500	89,000	94,500
41			69,500	73,500	78,500	84,000	89,500	95,000
42			70,000	74,000	79,000	84,500	90,000	95,500
43			70,500	75,000	80,000	85,000	90,500	96,000
44			71,500	75,500	80,500	85,500	91,000	96,500
45			72,000	76,000	81,000	86,000	91,500	97,500
46			72,500	76,500	81,500	87,000	92,500	98,000
47			73,500	77,500	82,000	87,500	93,000	98,500
48			74,000	78,000	83,000	88,000	93,500	99,000
49			74,500	78,500	83,500	88,500	94,000	99,500
50			75,500	79,000	84,000	89,000	94,500	100,000

Source: (5)

State and local transportation and law enforcement agencies issue permits for oversize and overweight trucks on Texas highways and monitor whether these vehicles properly follow the weight regulations and travel on their assigned routes. Traditionally, weight regulations are enforced through static truck weigh stations placed at specific locations on the roadway network or through portable wheel load scales (Figure 2).

CMV weigh station on I-35 near San Marcos, TX (Photo: Abu Faruk)

Truck axle weighing using static wheel load scales by DPS officials (Photo: Intercomp scales)

Figure 2. Weight Regulation Enforcement: Static Weigh Stations and Wheel Load Scales.

Current bridge collision avoidance technologies include mostly *visual low-clearance warning signs*, as shown in Figure 3.

Photo Credit: Joseph Novak

Photo Credit: WSDOT

Figure 3. Visual Low-Clearance Warning Signs.

Literature Review Findings: State-Implementable Technologies

This section summarizes the findings from the literature review for the technology categories that are ready for direct implementation by state agencies. Implementation entails both monitoring by TxDOT and enforcement by DPS.

Virtual WIM Stations

WIM stations measure and analyze dynamic vehicle tire forces to estimate the corresponding axle weights and GVW. WIM stations are most commonly used for collecting traffic volume and weight data. However, they can also be used for enforcing weight regulations.

The fundamental concept of this technology category is the use of WIM systems coupled with automatic vehicle identification (AVI) systems using a camera and optical character recognition (OCR) software. Technology suppliers offer different options for how the virtual WIM system can be used to enforce weight regulations. Two such options are:

- Option 1: The virtual WIM (V-WIM) system is coupled with a digital warning sign post that instructs violating vehicles to leave the highway or to take an exit to the nearby static weigh station for further weight evaluation and verification (Figure 4, Option 1).
- Option 2: The data are wirelessly transmitted to the enforcement agent, who then evaluates the vehicle using portable weight scales (Figure 4, Option 2).

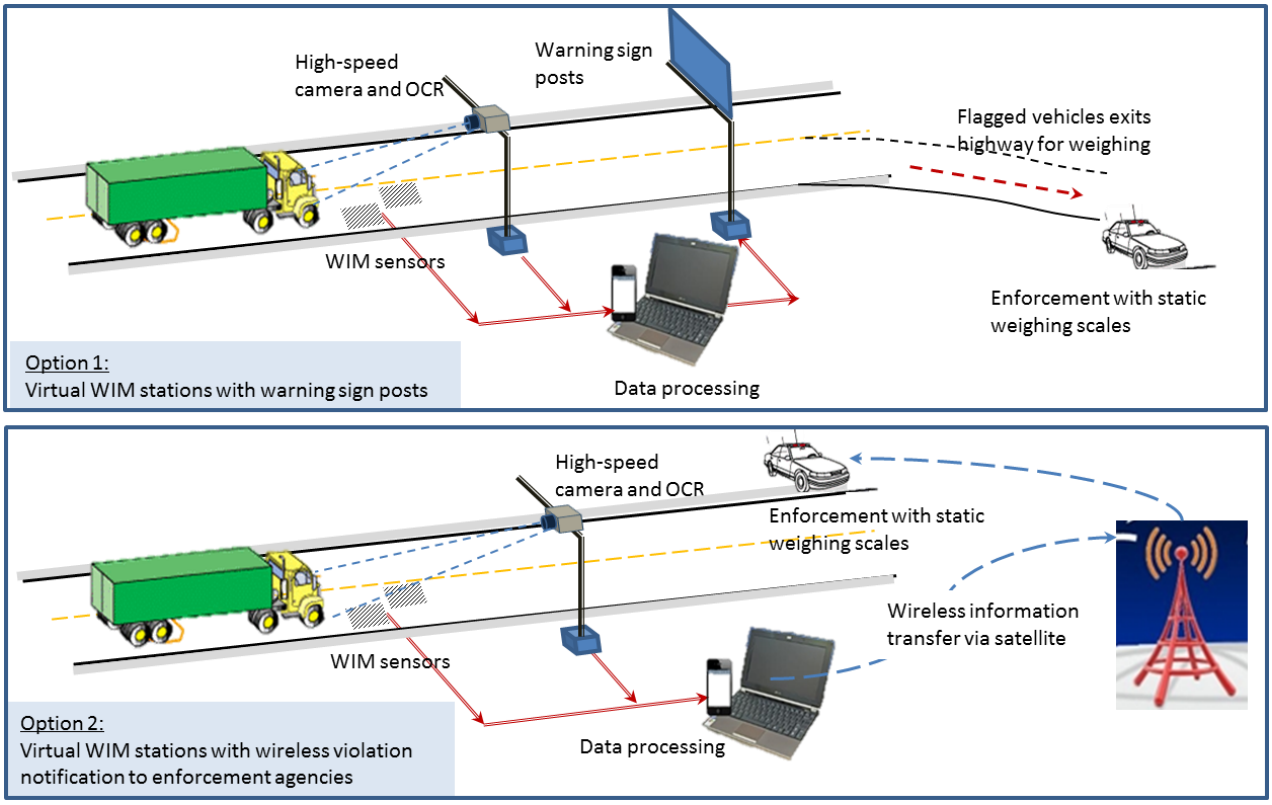


Figure 4. Schematic Diagram of V-WIM System.

A combination of these two options can also be applied to fit specific weight-enforcement needs. Almost all V-WIM system developers offer the option of transmitting the information wirelessly to a central storage and monitoring unit.

In general, such a technological system has the following advantages:

- Efficient enforcement of weight regulations.
- Reduced traffic congestion and delays at the weigh station.
- Automated (unmanned) system.
- Reduced fuel and operation costs for the trucking company.
- Reduced environmental impact.

Some of the limitations and challenges of this system include:

- High equipment and installation costs.
- Fixed location.
- Possibility of errors because of conversion of images to numeric data.

Researchers identified five available V-WIM systems from the Internet search. These five systems were subsequently compared based on their respective vendor-provided product information and available literature. Table 3 summarizes the findings for these systems.

Table 3. Comparative Summary of V-WIM Technologies.

Category	Cardinal	Intercomp	IRD	Mettler Toledo	PrePass
Technological concept	WIM sensors are coupled with camera imaging (OCR). The vehicle record is transmitted wirelessly to the enforcement officer's laptop.				Participating CMVs are prescreened to bypass weigh stations
Accuracy and reliability	2–6% error rate	High (temperature compensation)	Moderate (needs calibration)	No accuracy information available	No accuracy information available
Simplicity of operation and user-friendliness	All V-WIM systems provide simple operation and user-friendly service with minimal time and effort wasted on the trucker's part.				
Ease of installation	The system needs a permanently installed WIM and camera/OCR equipment. It is intrusive because it requires digging up the pavement to install WIM sensors.				
Maintenance and sustainability	Limited maintenance required	Easy maintenance	High life expectancy for load cells	iSYNC module for self-maintenance	Easy maintenance
Cost per unit	$25,000 to $45,000	$20,000	$32,000	$125,000 to $135,000	$45,000 to $55,000
Data source	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier
Reference	(*6*)	(*7*)	(*8*)	(*9*)	(*10*)

Among the five technologies compared, only PrePass offers a slightly different service than the other four. The Cardinal, Intercomp, IRD, and Mettler Toledo V-WIM systems monitor all vehicles that pass the facility; the PrePass system monitors only participating transponder-equipped CMVs. PrePass prescreens CMVs for overweight only and allows them to bypass the weigh stations. In other words, the PrePass facilities are installed next to a traditional weigh station, and to be able to benefit from the facility and bypass the weigh station, the CMV needs to be equipped with a transponder.

Portable WIM Systems

Portable WIM systems are handy and inexpensive alternatives to permanent WIM stations, and can be easily used to monitor and enforce overweight violations. However, traditionally, portable WIM systems have only been used for collecting and analyzing traffic volume and load data. To use these systems for enforcement purposes, the systems have to be modified/ enhanced by coupling with AVI systems and programmed to trigger or take a picture whenever an overweight vehicle is detected. An alternative approach is to couple the portable WIM with variable message signs that readily display the vehicle weight information to aid the enforcing authorities (*11*).

Using the available literature and product information, researchers compared five portable WIM systems. Table 4 summarizes the findings for these systems.

Table 4. Comparative Summary of Portable WIM Systems.

Category	TRS Portable WIM	DAW 300 Dynamic Axle Weigher	ECM Portable WIM	Intercomp	Massload
Technological concept	Portable WIM with piezo-electric sensors	Portable WIM using weighing plates	Portable WIM with piezo-electric sensors	Portable WIM with wireless weighing technology	Portable WIM with heavy-duty ultra-slim wheel load scales
Accuracy and reliability	Fairly accurate (±15%)	Highly accurate (±3%)	Fairly accurate (±10 to 15%)	Highly accurate (2 to 3%)	Highly accurate (±3%)
Simplicity of operation and user-friendliness	Simple and automatic. Data collection for vehicle speeds ≥20 mph.	Slightly more complicated. Low speed (<6 mph). Operator presence required.	Simple and automatic. Data collection at regular highway speed.	Low speed (<3 mph).	Low speed (<10 mph).
Ease of installation	Very easy (<2 hours)	Relatively more complicated	Fairly easy	Very easy (<15 minutes)	Very easy (<1 hour)
Maintenance and sustainability	Requires calibration at every site	No information available	No information available	Easy maintenance	Easy maintenance
Cost	$11,911	Ramp installation (Bluetooth) $37,841. Pit installation (wired) $25,073.	$25,000	$25,500	$19,117
Data source	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier
References	(*12*)	(*13*)	(*14*)	(*15*)	(*16*)

Portable Scales

Portable wheel load scales for weighing truck axles are a traditional way of enforcing weight regulations. In this study, state-of-the-art static axle weight scales were comparatively reviewed to be used by both truckers and enforcement agencies. Unlike certified scales consisting of large

decks for weighing the entire truck at a time, portable wheel load scales are lightweight and compact, and are designed to weigh each wheel or axle separately. Figure 5 shows some examples of portable wheel load scales.

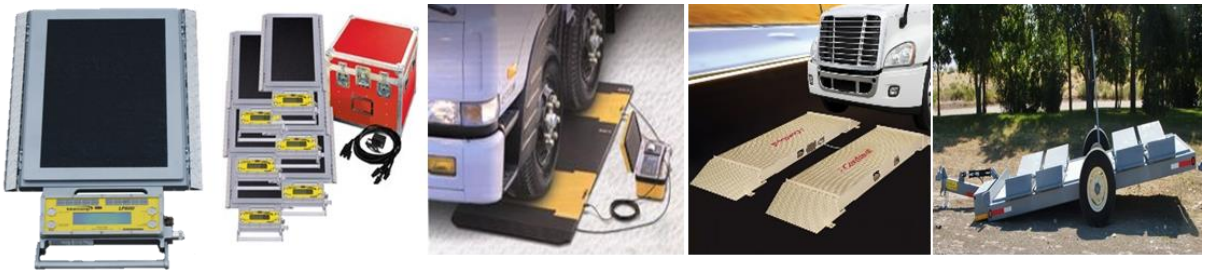


Figure 5. Portable Wheel Load Scales.

Using the available literature and product information, researchers compared five portable scales. Table 5 summarizes the findings for these systems.

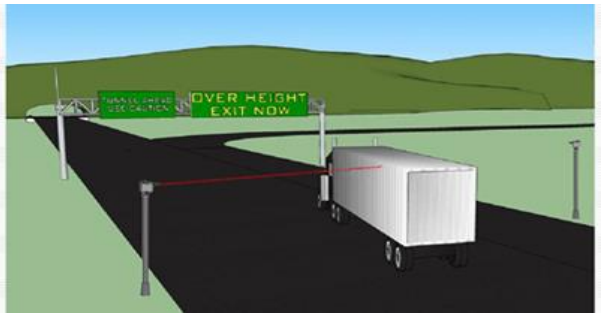
Table 5. Comparative Summary of Portable Scales.

Category	Intercomp PT 300	Intercomp LP 630*	CAS RWP Road Weighing Plate	Cardinal 760 PS/PA	Hydraulic Portable Scales
Technological concept	Multiple scales wirelessly coupled together to obtain GVW		Aluminum weighing platform	Weighing plates with load cells	Hydraulic scale pulled behind a truck
Accuracy and reliability	Highly accurate (99%)	Highly accurate (±1%)	Highly accurate (±1%)	±20 lb	Highly accurate (99.7%)
Simplicity of operation and user-friendliness	Simple operation (wireless)	Lightweight and compact, wireless data transfer	Lightweight and compact, remote display	Simple operation	Fairly simple
Ease of Installation	Very easy	Very easy	Portable	Portable	Fast installation (<5 minutes)
Maintenance and sustainability	Easy maintenance	Easy maintenance	Easy maintenance	Difficult to maintain	Needs frequent calibration
Cost	$6,500	$26,000	$3,295	$12,168	$ 13,500
Data source	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier
References	(*17*)	(*17*)	(*18*)	(*19*)	(*20*)

*On DPS's list of approved weight scales for law enforcement purposes (*21*).

Bridge Collision Avoidance Technologies

In addition to reviewing technologies for monitoring overweight vehicle loads and movements, researchers also identified the safety hazard posed by oversize (overheight) vehicles to low-clearance bridges as a relevant and pressing issue. The technological systems to avoid such incidents largely involve installing an over height detector and warning sign posts for vehicles approaching a low-clearance bridge. Both automatic (radar based) and manual (tattle-tale) overheight detector techniques are available. Figure 6 illustrates the fundamental concept of this approach.



Schematic of radar based over-height detection system

Tattle-tale over-height detection system
(Photo: Abu Faruk)

Figure 6. Bridge Collision Avoidance Systems.

Using the available literature and product information, researchers compared three technological systems. Table 6 summarizes the findings for these systems.

Table 6. Comparative Summary of Bridge Collision Avoidance Systems.

Category	Trigg DB-R/IR-3200	Trigg 3403-Z	Tattletale Overheight Detection
Technological concept	System includes a radar overheight detector with warning signs		Long-hanging tubes/chains used as overheight detector
Accuracy and reliability	High accuracy (radar)	High accuracy (radar)	Manual system
Simplicity of operation and user-friendliness	Very simple	Very simple	Fairly simple
Ease of installation	Requires installing overheight detector near every low-clearance bridge		
Maintenance and stability	Minimal maintenance	Minimal maintenance	Periodic maintenance and calibration
Cost	$9,259	$14,427	$20,000
Data source	Vendor/supplier	Vendor/supplier	Vendor/supplier
References	(*22*)	(*22*)	(*23*)

Literature Review Findings: Self-Enforcement Technologies

This section summarizes the findings from the literature review for the technology categories that are more suitable for self-regulation or self-enforcement by the trucking industry. The implementation of the technologies in this category for enforcement purposes requires industry participation through installation of certain device(s) in their vehicles or at their loading facilities.

From a policy perspective, these technologies might not be immediately implementable as far as the state transportation agencies are concerned. However, these technologies have clear benefits to the trucking industry in terms of reducing time spent at the weigh stations and can be useful for enforcing weight regulations if industry participation can be ensured. Therefore, researchers reviewed these technologies and included them in this policy brief.

Remote Measurement of Axle Weights (Onboard Weight Scales)

The fundamental concept of this technological category is as follows:

1. Load gauges are attached to vehicle axles and measure individual axle loads.
2. The load gauges transmit these data to an in-cabin master unit through wireless communication.
3. The in-cabin unit transmits the load data to monitoring/enforcing authorities using Bluetooth, code division multiple access (CDMA), or global system for mobiles (GSM) technologies.

Figure 7 presents a schematic diagram of this technological concept *(24-28)*.

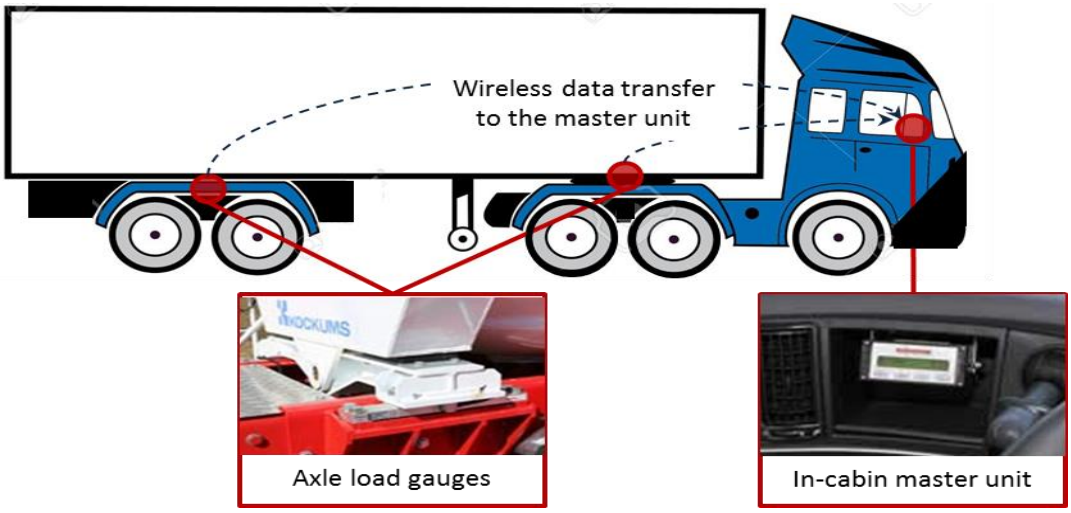


Figure 7. Schematic Diagram of Remote Measurement of Axle Weights.

Advantages of this technological concept include:

- Efficient wireless enforcement of vehicle weight regulations.
- Reliable and accurate technology.
- Reduced expense and lost time at public weigh stations.

Limitations and challenges of such a system include the following:

- The trucker installs and maintains the system; thus, enforcement is reliant on the user's compliance.
- Custom-designed scales are required for different truck types.
- The system is dependent on network availability if using wireless communication (CDMA or GSM).

Using the available literature and product information, this study compared five onboard weight scale technologies. Table 7 summarizes the findings.

Table 7. Comparative Summary of Remote Measurement Technologies.

Category	Loadman	Airtec	CHEK-WAY Eliminator	Vulcan V700	Truck Weight Smart Scale
Technological concept	Onboard load gauges measure axle loads and transmit wirelessly to monitoring/enforcing agencies			Onboard load gauges measure axle loads and transmit wirelessly to a nearby monitoring unit	
Accuracy and reliability	High (99%)	No accuracy information available	No accuracy information available	High (99%)	Very high (99.7%)
Simplicity of operation and user-friendliness	Very good	Good	Good	Limited (no software for remote monitoring)	Limited (no software for remote monitoring)
Ease of installation	Easy installation (custom designed)	Easy installation	Relatively difficult (wired connection)	No information available	Easy
Maintenance and sustainability	Very easy (5-year warranty on scales)	Easy (12-month warranty)	Fairly easy	Calibration required annually	No information available
Cost	$3,000 to $10,000	$786	$2,000	$1,420	$13,000 to $15,000
Data source	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier
References	(*24*)	(*25*)	(*26*)	(*27*)	(*28*)

Among the five technologies compared, the Loadman, Airtec, and CHEK-WAY Eliminator provide options for transmitting vehicle weight information to a central monitoring facility and are therefore most suitable for weight-monitoring and enforcement purposes. The Vulcan V700 and the Truck Weight Smart Scales, on the other hand, can only transmit the individual axle weight data to a central in-cabin or handheld mobile unit. Thus, these two products are more suitable for use by the individual truckers as a self-enforcing measure.

Vehicle Telematics

Telematics is the combination of global positioning system (GPS) navigation, telecommunication, and informatics systems that can monitor the location, movements, and status of a CMV or a fleet of vehicles through a communication device installed in each vehicle. Currently, vehicle telematics systems are used mostly as fleet management tools by trucking companies. However, the system can potentially be used to monitor movements of heavy CMVs to ensure that they remain on their assigned routes. Figure 8 presents a schematic diagram of the vehicle telematics concept *(29-32)*.

Figure 8. Schematic Diagram of Vehicle Telematics System.

Advantages of vehicle telematics include:

- Efficient monitoring of permitted overweight vehicle movements.
- Increased safety.
- Prevention of pavement damage to roads not designed for overweight loads.

Limitations and challenges of vehicle telematics include the following:

- The trucker installs and maintains the system; thus, enforcement is reliant on the user's compliance.
- An Internet/satellite signal is required.
- The system needs modification to be better suited for the specific purpose of freight monitoring and enforcement, as opposed to the current use as a freight management tool.

Using the available literature and product information, researchers compared five vehicle telematics systems. Table 8 summaries the findings.

Table 8. Comparative Summary of Vehicle Telematics Technologies.

Category	Skyrunner II	Coyote RT	Live Trac EZ	Live Trac G5 Pro	Smart Telematics
Technological concept	GPS navigation, telecommunication, and informatics systems are combined to monitor location and movement of CMV fleets				
Accuracy and reliability	Satellite accuracy up to 10 ft	Less accurate than Skyrunner II	Fairly accurate (web based)	No information available	No information available
Simplicity of operation and user-friendliness	Very good	Very good	Very good	Very good	Very good
Ease of installation	Simple 3-wire installation	Simple 3-wire installation	Plug and play	Plug and play	Installation by supplier
Maintenance and sustainability	Practically no maintenance	Practically no maintenance	Practically no maintenance	Practically no maintenance	Full hardware warranty, 24/7 customer service
Cost	Initial cost $185 + $22/vehicle/month		$169 + $29.95/month	$239 + $29.95/month	$135
Data source	Vendor/supplier		Vendor/supplier	Vendor/supplier	Vendor/supplier
References	(*29*)	(*29*)	(*30*)	(*31*)	(*32*)

Permits with Tracking Codes

The technological concept explored in this category is fairly similar to vehicle telematics. When overweight vehicle permits are issued, the vehicles and fleets are supplied with tracking devices enabling the monitoring and enforcing authorities to remotely track the location and movement of the permitted vehicles. If permits are secured online, the system can be modified so that the users are required to show proof or confirmation (code/number) that they have acquired the tracking device from a list of state-authorized/approved sources. Figure 9 presents the concept schematically *(33-37)*.

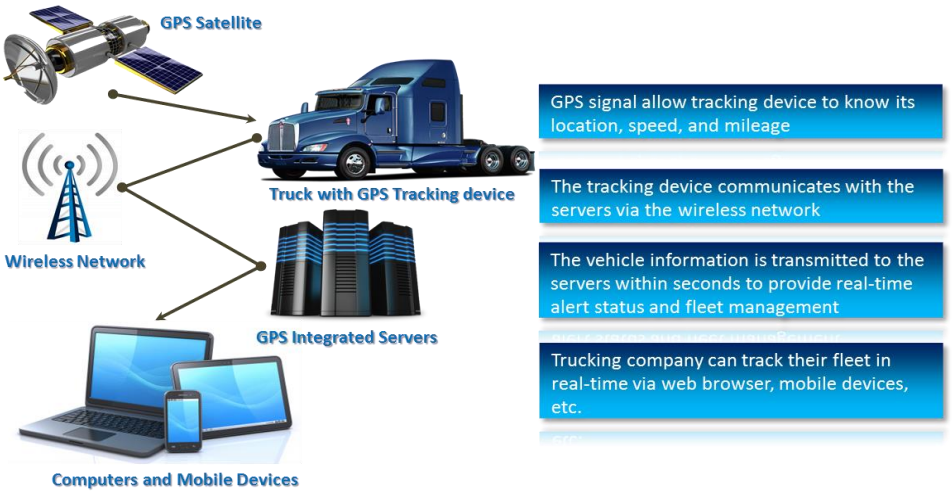


Figure 9. Schematic Diagram of Permitted Trucks with GPS Tracking Devices.

Advantages of these systems include:

- Efficient monitoring of overweight vehicle movements.
- Increased safety.
- Prevention of pavement damage to roads not designed for overweight loads.

Limitations and challenges of these systems include the following:

- The trucker installs and maintains the system; thus, enforcement is reliant on the user's compliance.
- An Internet/satellite signal is required.
- The system needs modification and optimization to be better suited for the specific purpose of freight monitoring and enforcement, as opposed to the current use as a freight management tool.

Using the available literature and product information, researchers reviewed five GPS-based tracking device systems. Table 9 summaries the findings.

Table 9. Comparative Summary of GPS-Based Tracking Systems.

Category	Fleetmatics	Teletrac	Telenav	Fleet Sphere	BrickHouse Security
Technological concept	Permitted trucks are supplied with GPS-based tracking devices so that the enforcing agencies can monitor their movements to ensure a specified route is being followed				
Accuracy and reliability	1.5 meters	99% accuracy	Location accuracy = 2 meters	No information available	No information available
Simplicity of operation and user-friendliness	Very easy	Very easy	Simple	Very easy	Very easy
Ease of installation	Easy	Free installation by the company	Very easy (plug and play)	Easy	Very easy (plug and play)
Maintenance and sustainability	Free (lifetime warranty)	Lifetime warranty on hardware and software	Lifetime warranty on hardware and software	No information available	90-day warranty
Cost	$0 + $37/month	$0 + $30 to $70/month	$250 + $28/month	No information available	$119 + $30/month
Data source	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier
References	(*33*)	(*34*)	(*35*)	(*36*)	(*37*)

Certified Scales for Self-Weight

The fundamental concept of this technology category is the issuance of certified scales to be used by truckers for self-weighing as the first document on enforcement. The truckers themselves log the weight information in a logbook, which can be presented to a law enforcement officer upon request. This provides a faster and more efficient way of acquiring vehicle weight information.

From a policy perspective, the weight-logbook system can be declared as a document that truckers are required to carry and present to the law enforcement officer whenever stopped. Similarly, truckers can also be required to have the certified self-weight scales in the CMVs or at their loading facilities.

The scales will be required to be certified by the authorities and can be portable or semi-portable in nature. The CMV can carry portable scales so that operators can check the weight being carried any time they need to. Also, the semi-portable scales can be installed in the loading facilities permanently or for a desired period of time to make sure allowable weight limits are not exceeded while loading. Figure 10 shows some examples of truck scales for self-weighing.

Figure 10. Certified Truck Weighing Scales for Self-Weighing.

Using the available literature and product information, researchers compared five scales. Table 10 summarizes the findings.

Table 10. Comparative Summary of Certified Scales for Self-Weight.

Category	LOADMASTER FT2-PV	Fairbanks Talon	Fairbanks Titan	Cardinal EPR	Cardinal PRC
Technological concept	Steel/concrete decks containing load cells for measuring truck weights				
Accuracy and reliability	Highly accurate (>99%)	No information available	No information available	±20 lb	High (uses load cell)
Simplicity of operation and user-friendliness	More manpower required in operation	Fairly simple	Fairly simple	Simple but operator required	Semi-portable
Ease of installation	Long setup time	Easy	Relatively longer setup time	Relatively easy	Relatively longer setup time
Maintenance and sustainability	Needs calibration	No information available	No information available	Uses load cells, hard to maintain but usually high life expectancy	
Cost	$42,000	$73,000	$81,000	$45,000	$45,000
Data source	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier	Vendor/supplier
References	(*38*)	(*39*)	(*39*)	(*40*)	(*40*)

Conclusions

Based on the extensive literature review of currently available technological systems, researchers identified eight possible components of the intelligent vehicle monitoring system for enhanced enforcement of truck weight and size regulations. Among these, four technological systems are directly implementable by transportation agencies, and four are more suited as self-enforcement tools to be used by the trucking industry. The technology components are as follows:

- Technologies directly implementable by the state:
    1. V-WIM stations.
    2. Portable WIM systems.
    3. Portable scales.
    4. Bridge collision avoidance technologies.
- Self-regulation or self-enforcement technologies (non-state implementable):
    1. Remote measurement of axle weights.
    2. Vehicle telematics.
    3. Permits with tracking codes.
    4. Certified scales for self-weight.

Tables 11 and 12 provide summaries of the technologies and the associated costs.

Even though the technologies listed in Table 12 are not suitable for direct implementation by the transportation agencies, the technologies can act as an important component of an intelligent freight monitoring and regulating system if industry participation can be ensured. All of these technologies offer intrinsic benefits to trucking companies by saving time, resources, and money.

With the exception of permanent WIM stations, the reviewed technological systems provide non-invasive solutions to the issues of overweight/oversize vehicle operations.

Table 11. Summary of Technologies Directly Implementable by the State and Their Costs.

No.	Description	Product	Cost	Key Technological Feature
1	V-WIM stations	Cardinal	$25,000 to $45,000	Detects overweight and bridge formula violations; laser-based overheight detection
		Intercomp	$20,000	Detects overweight violations
		IRD	$32,000	
		Mettler Toledo	$125,000 to $135,000	
		PrePass	$45,000 to $55,000	Participating CMVs are prescreened to bypass weigh stations
2	Portable WIM systems	TRS Portable WIM	$11,911	Vehicle speeds ≥20 mph
		ECM Portable WIM	$25,000	High-speed portable WIM
		Intercomp	$25,500	Highly accurate weight measurement (low speed)
		DAW 300 Dynamic Axle Weigher	$37, 841	
		Massload	$19,117	
3	Portable scales	Intercomp FRX Wireless	$14,500	Wireless data transfer
		Intercomp LP 630	$26,000	
		CAS RWP Road Weighing Plate	$3,295	Lightweight and compact portable scales
		Cardinal 760 PS/PA	$12,168	
		Hydraulic Portable Scales	$13,500	Hydraulic scale pulled behind a truck
4	Bridge collision avoidance technologies	Trigg DB-R/IR-3200	$9,259	Radar overheight detector placed before low-clearance bridges
		Trigg 3403-Z	$14,427	
		Tattle-tale Overheight Detection	$20,000	Long-hanging tubes/chains used as overheight detector

Table 12. Summary of Self-Regulation or Self-Enforcement Technologies (Non-State Implementable) and Their Costs.

No.	Description	Product	Cost	Key Technological Feature
1	Remote measurement of axle weights	Loadman	$3,000 to $10,000	Custom-designed scales for different truck types
		Airtec	$786	Low-cost onboard scales; remote monitoring of fleet/truck weights
		CHEK-WAY Eliminator	$2,000	
		Vulcan V700	$1,420	Onboard load gauges measure axle loads and transmit wirelessly to a nearby monitoring unit
		Truck Weight Smart Scale	$13,000 to $15,000	
2	Vehicle telematics	Skyrunner II	$185 + $22/vehicle/month	GPS- and satellite-based services for monitoring permitted truck movement
		Coyote RT		
		Live Trac EZ	$169 + $29.95/month	
		Live Trac G5 Pro	$239 + $29.95/month	
		Smart Telematics	$135	
3	Permits with tracking codes	Fleetmatics	$37/month	GPS- and satellite-based services for monitoring permitted truck movement
		Teletrac	$30 to $70/month	
		Telenav	$250 + $28/month	
		Fleet Sphere	No information	
		BrickHouse Security	$119 + $30/month	
3	Certified scales for self-weight	LOADMASTER FT2-PV	$42,000	Steel/concrete decks containing load cells for measuring truck weights; portable or semi-portable
		Fairbanks Talon	$73,000	
		Fairbanks Titan	$81,000	
		Cardinal EPR	$45,000	
		Cardinal PRC	$45,000	

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