Compliance Comparative Analysis Technical Report

Comprehensive Truck Size and Weight Limits Study

June 2015

U.S. Department of Transportation

Federal Highway Administration

EXECUTIVE SUMMARY

Background

This report documents analyses conducted as part of the U.S. Department of Transportation (USDOT) *2014 Comprehensive Truck Size and Weight Limits Study* (2014 CTSW Study). As required by Section 32801 of MAP-21 [Moving Ahead for Progress in the 21st Century Act (P.L. 112-141)], Volumes I and II of the 2014 CTSW Study have been designed to meet the following legislative requirements:

- Subsection 32801 (a)(1): Analyze accident frequency and evaluate factors related to accident risk of vehicles to conduct a crash-based analyses, using data from States and limited data from fleets;
- Subsection 32801 (a)(2): Evaluate the impacts to the infrastructure in each State including the cost and benefits of the impacts in dollars; the percentage of trucks operating in excess of the Federal size and weight limits; and the ability of each State to recover impact costs;
- Subsection 32801 (a)(3): Evaluate the frequency of violations in excess of the Federal size and weight law and regulations, the cost of the enforcement of the law and regulations, and the effectiveness of the enforcement methods; Delivery of effective enforcement programs;
- Subsection 32801 (a)(4): Assess the impacts that vehicles have on bridges, including the impacts resulting from the number of bridge loadings; and
- Subsections 32801 (a)(5) and (6): Compare and contrast the potential safety and infrastructure impacts of the current Federal law and regulations regarding truck size and weight limits in relation to six-axle and other alternative configurations of tractor-trailers; and where available, safety records of foreign nations with truck size and weight limits and tractor-trailer configurations that differ from the Federal law and regulations. As part of this component of the study, estimate:
  - (A) the extent to which freight would likely be diverted from other surface transportation modes to principal arterial routes and National Highway System intermodal connectors if alternative truck configuration is allowed to operate and the effect that any such diversion would have on other modes of transportation;
  - (B) the effect that any such diversion would have on public safety, infrastructure, cost responsibilities, fuel efficiency, freight transportation costs, and the environment;
  - (C) the effect on the transportation network of the United States that allowing alternative truck configuration to operate would have; and
  - (D) the extent to which allowing alternative truck configuration to operate would result in an increase or decrease in the total number of trucks operating on principal arterial routes and National Highway System intermodal connectors.

To conduct the study, the USDOT, in conjunction with a group of independent stakeholders, identified six different vehicle configurations involving six-axle and other alternative configurations of tractor-trailer as specified in Subsection 32801 (a)(5), to assess the likely results of allowing widespread alternative truck configurations to operate on different highway networks. The six vehicle configurations were then used to develop the analytical scenarios for each of the five comparative analyses mandated by MAP-21. The use of these scenarios for each of the analyses in turn enabled the consistent comparison of analytical results for each of the six vehicle configurations identified for the overall study.

The results of this *2014 Comprehensive Truck Size and Weight Limits Study* (2014 CTSW Study) are presented in a series of technical reports. These include:

- *Volume I: Comprehensive Truck Size and Weight Limits Study – Technical Summary Report.* This document gives an overview of the legislation and the study project itself, provides background on the scenarios selected, explains the scope and general methodology used to obtain the results, and gives a summary of the findings.
- *Volume II: Comprehensive Truck Size and Weight Limits Study.* This volume comprises a set of the five comparative assessment documents that meet the technical requirements of the legislation as noted:
    - *Modal Shift Comparative Analysis* (Subsections 32801 (a)(5) and (6)).
    - *Pavement Comparative Analysis* (Section 32801 (a)(2)).
    - *Highway Safety and Truck Crash Comparative Analysis* (Subsection 32801 (a)(1)).
    - *Compliance Comparative Analysis* (Subsection 32801 (a)3)).
    - *Bridge Structure Comparative Analysis* (Subsection 32801 (a)(4)).

<u>Purpose of the Compliance Comparative Analysis</u>

The purpose of this report is to assess the cost and effectiveness of enforcing truck size and weight (TSW) limits for trucks currently operating at or below current Federal truck weight limits as compared with a set of alternative truck configurations in six scenarios.

The first three of the six scenarios asses the impacts of heavier tractor semitrailers than are generally allowed under current Federal law. Scenario 1 would allow five-axle (3-S2) tractor semitrailer to operate at a maximum gross vehicle weight (GVW) of 88,000 lb. while Scenarios 2 and 3 would allow six-axle (3-S3) semitrailers to operate at maximum GVWs of 91,000 lb. and 97,000 lb., respectively.

Scenarios 4, 5 and 6 examine vehicles that would serve primarily lower density cargoes commonly associated with those trucks that carry cargo from more than one shipper (known as less-than-truckload traffic or LTL). Scenario 4 examines twin trailer combination with 33-foot trailers (2-S1-2) with a maximum GVW of 80,000 lbs. Scenarios 5 and 6 examine triple trailer combinations with 28 or 28.5-foot trailers having maximum GVWs of 105,500 lb. (2-S1-2-2) and 129,000 lb. (3-S2-2-2), respectively.

At this point it is important to note that while the control double has an approved GVW of 80,000 pounds, the GVW used for the control double in the study is 71,700 pounds based on actual data collected from weigh-in-motion (WIM)-equipped weight and inspection facilities and is a more accurate representation of actual vehicle weights than the STAA authorized

GVW. Using the WIM-derived GVW also allows for a more accurate representation of the impacts generated through the six scenarios.

Table ES-1 on the following page depicts the vehicles assessed under each scenario as well as the current vehicle configurations from which most traffic would likely shift (the control vehicles).

This *Compliance Comparative Analysis* is supported by a comprehensive scan of recent literature and insights obtained from TSW enforcement stakeholders and experts from around the world (**Appendices A and B**).

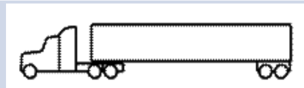
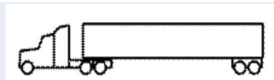
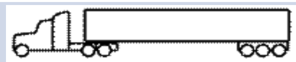
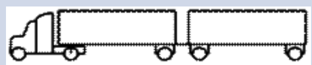
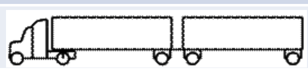
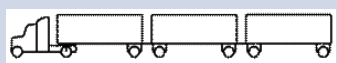
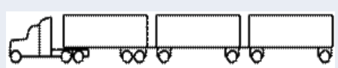
The cost analysis portion of this study includes a description of the principal TSW enforcement methods used in the United States, including the application of enforcement technologies, meaning that the enforcement costs assessed reflect the resources required to undertake the truck size and weight enforcement task. The analysis examines national-level trends in enforcement program costs and conducts enforcement cost comparisons between States and for different truck configurations. Finally, the analysis estimates the enforcement cost impacts of introducing the alternative truck configurations into the traffic stream.

Enforcement program effectiveness reflects how the resources provided to the enforcement program translate into TSW enforcement actions and ultimately contribute to achieving regulatory compliance. The effectiveness analysis examines trends and relationships pertaining to enforcement program activities (such as truck weighings) and compares effectiveness between States and for different truck configurations. WIM data gathered at sites where alternative truck configurations currently operate provide the basis for comparing the compliance impacts of introducing these configurations into the traffic stream.

Methodology

Despite the widely held notion of a linkage between truck weight enforcement and compliance, there remains an inability to fully understand this relationship because of differences in how enforcement occurs and a lack of systematic and reliable evidence concerning overweight trucking. Additionally, understanding this relationship for specific truck configurations—one of the main issues of interest in this 2014 CTSW Study—has generally been constrained by insufficient data. Increasing investments in proven enforcement technologies, including tools for identifying non-compliant trucks or carriers and the expanded use of WIM devices for monitoring truck weights, provide some opportunity to address these historical data limitations; however, certain data gaps persist which preclude a definitive analysis of the subject.

Table ES-1. Truck Configuration and Weight Scenarios Analyzed in the 2014 CTSW Study

Scenario	Configuration	Depiction of Vehicle	# Trailers or Semi-trailers	# Axles	Gross Vehicle Weight (pounds)	Roadway Networks
Control Single	5-axle vehicle tractor, 53 foot semitrailer (3-S2)		1	5	80,000	STAA[1] vehicle; has broad mobility rights on entire Interstate System and National Network including a significant portion of the NHS
1	5-axle vehicle tractor, 53 foot semitrailer (3-S2)		1	5	88,000	Same as Above
2	6-axle vehicle tractor, 53 foot semitrailer (3-S3)		1	6	91,000	Same as Above
3	6-axle vehicle tractor, 53 foot semitrailer (3-S3)		1	6	97,000	Same as Above
Control Double	Tractor plus two 28 or 28 ½ foot trailers (2-S1-2)		2	5	80,000 maximum allowable weight 71,700 actual weight used for analysis[2]	Same as Above
4	Tractor plus twin 33 foot trailers (2-S1-2)		2	5	80,000	Same as Above
5	Tractor plus three 28 or 28 ½ foot trailers (2-S1-2-2)		3	7	105,500	74,500 mile roadway system made up of the Interstate System, approved routes in 17 Western States allowing triples under ISTEA Freeze and certain four-lane PAS roads on East Coast[3]
6	Tractor plus three 28 or 28 ½ foot trailers (3-S2-2-2)		3	9	129,000	Same as Scenario 5[3]

[1] The STAA network is the National Network (NN) for the 3-S2 semitrailer (53') with an 80,000-lb. maximum GVW and the 2-S1-2 semitrailer/trailer (28.5') also with an 80,000 lbs. maximum GVW vehicles. The alternative truck configurations have the same access off the network as its control vehicle.

[2] The 80,000 pound weight reflects the applicable Federal gross vehicle weight limit; a 71,700 gross vehicle weight was used in the study based on empirical findings generated through an inspection of the weigh-in-motion data used in the study.

[3] The triple network is 74,454 miles, which includes the Interstate System, current Western States' triple network, and some four-lane highways (non-Interstate System) in the East. This network starts with the 2000 CTSW Study Triple Network and overlays the 2004 Western Uniformity Scenario Analysis, Triple Network in the Western States. There had been substantial stakeholder input on networks used in these previous USDOT studies and use of those provides a degree of consistency with the earlier studies. The triple configurations would have very limited access off this 74,454 mile network to reach terminals that are immediately adjacent to the triple network. It is assumed that the triple configurations would be used in LTL line-haul operations (terminal to terminal). The triple configurations would not have the same off network access as its control vehicle–2-S1-2, semitrailer/trailer (28.5'), 80,000 lbs. GVW. The 74,454 mile triple network includes: 23,993 mile network in the Western States (per the 2004 Western Uniformity Scenario Analysis, Triple Network), 50,461 miles in the Eastern States, and mileage in Western States that was not on the 2004 Western Uniformity Scenario Analysis, Triple Network but was in the 2000 CTSW Study, Triple Network (per the 2000 CTSW Study, Triple Network).

The analysis of costs and effectiveness undertaken in this study takes a performance-based approach. This approach considers enforcement program performance (or effectiveness) in terms of inputs, outputs, outcomes, and pertinent relationships between these measures. Enforcement program inputs reflect the resources (i.e., personnel, facilities, technologies) available to carry out the TSW enforcement task. State Enforcement Plans (and the subsequent certification of these plans) submitted by each State are the principal data source used to analyze program inputs.

Outputs reflect the way enforcement resources are used, the scale or scope of activities performed, and the efficiency of converting allocated resources into a product (e.g., quantity of weighings, weight citations). These output measures are sourced from the Annual Certifications of Truck Size and Weight Enforcement database. While these outputs on their own provide some indication of program effectiveness, additional outputs and inputs can improve the overall understanding of program effectiveness.

The relationship between citation rate and enforcement intensity (measured as the number of weighings per truck vehicle-miles of travel) is one example. Outcomes reflect the degree of success of the TSW enforcement program in achieving its goal, which from an operational and programmatic perspective, is to achieve compliance with TSW regulations. The outcome measures used in this study are the proportion of axle or truck observations that fall within the Federal weight compliance limits compared to the severity of overweight observations.

Applying the performance-based approach provides the supporting framework for a comparative analysis designed to reveal insights about the costs and effectiveness of TSW enforcement programs. Data limitations, consistency, and availability constrain a comprehensive, representative understanding of these costs and effectiveness, particularly regarding vehicle-specific comparisons. To accommodate these limitations and leverage existing datasets and institutional knowledge, this study applies two types of comparisons:

- At a broad level, readily available State-specific data provides the foundation for comparing costs and effectiveness between States that currently allow trucks above Federal weight limits and those that do not. As the State-level data used in these comparisons do not allow disaggregation by vehicle configuration, these comparisons can be understood as a surrogate way of revealing potential vehicle-specific differences at a State level.
- A more detailed comparative analysis of enforcement program costs and effectiveness involves vehicle-specific comparisons (where possible). These comparisons focus on enforcement cost and effectiveness differences between the control vehicles and the six alternative truck configurations introduced into the traffic stream for the six 2014 CTSW Study scenarios. Thus, the results of the vehicle-specific comparisons directly support the scenario analysis, which estimates system-wide cost and effectiveness impacts that could result from the operation of the alternative truck configurations relative to the 2011 base case.

Summary of Results

Owing mainly to a lack of systematic and consistent data, prior research on TSW enforcement identifies the need for improved understanding of how enforcement resources, methods, and technologies can be effectively deployed to achieve better compliance. A configuration-specific understanding is particularly needed when considering the potential introduction of alternative truck configurations into the traffic stream, as is the case in this 2014 CTSW Study. The State-level and particularly the vehicle-specific comparisons conducted in this analysis leverage existing datasets and, together, reveal insights about potential differences in enforcement costs and effectiveness for trucks operating within current Federal sizes and weight limits versus alternative truck configurations with higher sizes and weights. Additionally, these comparisons support a system-wide estimation of overall cost and effectiveness impacts that could occur under the scenario conditions.

Key findings concerning enforcement **costs** follow:

- From a national-level programmatic perspective, States spent a total of approximately $635 million (in 2011 US Dollars) on their TSW enforcement programs in 2011. Personnel costs represented about 85 percent of total costs, while facilities expenditures (including investments in technologies) accounted for the remaining costs. Technologies play an important role in TSW enforcement and are increasingly deployed by State enforcement agencies.
- Based on the State-level comparisons, there is no indication of a change in enforcement costs that can be attributed to whether or not a State allows trucks to operate above Federal limits. Rather, differences in how States deliver enforcement programs (e.g., methods of enforcement used, technologies, intensity of enforcement) may have greater influential on total costs.
- The vehicle-specific comparative analysis indicates that, because the alternative truck configurations have more axles or axle groups than the control vehicles (except the Scenario 4 configuration with two 33-foot trailers), they will require more time to weigh using certain standard weighing equipment and thus result in higher personnel costs.
- When estimating cost impacts on a system-wide basis in the scenario analyses, personnel costs decrease because the reduction in VMT predicted by the scenarios necessitates fewer weighings overall (assuming the rate of weighing vehicles relative to VMT is held constant) and this outweighs the increased costs associated with weighing the alternative truck configurations. Viewed another way, the rate at which weighings occur (per VMT) or the time spent conducting a weighing could be increased under the scenario conditions for the same level of expenditures on enforcement personnel.

Key findings concerning enforcement **effectiveness** follow:

- Considering national-level trends, both the weighing cost-efficiency (personnel costs per non-WIM weighing) and citation rate (citations per non-WIM weighing) decreased during the period from 2008 to 2012. The relationship between citation rate and enforcement intensity revealed that the citation rate decreases as enforcement intensity increases (i.e., more weighings per million truck VMT), but reaches a point of diminishing return. Moreover, those States that conduct a higher proportion of portable and semi-portable weighings generally have a lower overall enforcement intensity and a higher citation rate. Measuring enforcement effectiveness in terms of a citation rate is complex because both relatively low and relatively high citation rates could be interpreted as a reflection of an effective enforcement program.

- Based on the State-level comparisons, as with the cost results, there is no indication of a change in enforcement effectiveness (as measured by the relationship between citation rate and enforcement intensity) that can be attributed to whether or not a State allows trucks to operate above Federal limits.
- For the vehicle-specific comparison of enforcement effectiveness, an analysis of data from selected WIM sites indicates that, except for six-axle tractor semitrailers operating off Interstates, the alternative truck configurations exhibit a higher proportion of compliant GVW observations than the control vehicles—hence our use of the 71,700 lb. average GVW for those calculations involving the control double configuration. However, for all the comparisons, the intensity of overweight observations is higher for the alternative truck configurations than the control vehicles.
- System-wide, in each of the scenarios analyzed, the impact on the proportion of total weight-compliant VMT for the control vehicle and alternative truck configuration is limited relative to the base case.

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LIST OF ACRONYMS

Acronym	Definition
AASHTO	Association of American State Highway and Transportation Officials
CFR	Code of Federal Regulations
CTSW	Comprehensive Truck Size and Weight Limits Study
FHWA	Federal Highway Administration
GVW	Gross vehicle weight
LCV	longer combination vehicles
LTL	Less than truckload
NHTSA	National Highway Traffic Safety Administration
OS/OW	oversize/overweight
USC	United States Code
USDOT	US Department of Transportation
VMT	vehicle miles traveled
VIUS	Vehicle Inventory and Use Survey
WHVC	World Harmonized Vehicle Cycle
WIM	weigh-in-motion

CHAPTER 1 – INTRODUCTION

1.1 Background

MAP-21 directs the Secretary of Transportation, in consultation with State and other Federal agencies, to conduct a series of analyses assessing the impacts from trucks operating at or within current Federal size and weight regulations as compared to the impacts from trucks operating above those limits with a particular focus on impacts to:

- Highway safety and truck crash rates;
- Infrastructure (pavement) service life;
- Highway bridge performance; and
- Delivery of effective enforcement programs.

The United Stated Department of Transportation (USDOT), in conjunction with a group of independent stakeholders, identified six different vehicle configuration scenarios, each involving one of the alternative truck configurations, to assess the likely results of allowing widespread alternative truck configurations to operate on different highway networks.

The results of this *2014 Comprehensive Truck Size and Weight Limits Study* (2014 CTSW Study) study are presented in a series of technical reports. These include:

- *Volume I: Comprehensive Truck Size and Weight Limits Study – Technical Summary Report.* This document gives an overview of the legislation and the study project iteself, provides background on the scenarios selected, explains the scope and general methodology used to obtain the results, and gives a summary of the findings.
- *Volume II: Comprehensive Truck Size and Weight Limits Stud.* This volume comprises a set of five comparative assessment documents that meet the technical requirements of the legislation:
    - *Modal Shift Comparative Analysis,*
    - *Pavement Comparative Analysis,*
    - *Highway Safety and Truck Crash Comparative Analysis,*
    - *Compliance Comparative Analysis*
    - *Bridge Structure Comparative Analysis*

The *Volume II: Compliance Comparative Analysis* presents the analysis of the six alternative truck size and weight configurations (scenarios) selected for study and describes in detail the approach, data, models, limitations, and assumptions underlying estimates of potential compliance impacts associated with the six scenarios.

1.2 Purpose

Meaningful control of truck size and weight (TSW) requires the enforcement of relevant laws and regulations. Effective enforcement programs seek to efficiently allocate resources and technological investments in a manner which achieves regulatory compliance, and ultimately improves safety, protects highway infrastructure, and promotes fairness within the road transport industry.

This report documents the results from the *Volume II: Compliance Comparative Analysis*, a component of the USDOT *2014 Comprehensive Truck Size and Weight Limits Study* (2014 CTSW Study). The purpose of this study is to assess the cost and effectiveness of enforcing TSW limits for trucks operating at or below current Federal truck weight limits as compared with enforcement costs and effectiveness for alternative truck configurations in six scenarios. The results of the comparative analyses of enforcement cost and effectiveness are reported in **Chapters 2 and 3** of this report, respectively.

Enforcement costs reflect the resources required to undertake the TSW enforcement task. The cost analysis includes a description of the principal TSW enforcement methods used in the United States, including the application and costs of enforcement technologies. The analysis examines national-level trends in enforcement program costs and conducts enforcement cost comparisons between States and for different truck configurations. Finally, the analysis estimates the enforcement cost impacts of introducing the alternative truck configurations into the traffic stream.

Enforcement program effectiveness reflects how the resources provided to the enforcement program translate into TSW enforcement actions and ultimately contribute to achieving regulatory compliance. The effectiveness analysis examines trends and relationships pertaining to enforcement program activities (such as truck weighings) and compares effectiveness between States and for different truck configurations. Weigh-in-motion (WIM) data gathered at selected sites provides the basis for comparing the truck weight compliance impacts that may result from introducing the alternative truck configurations into the traffic stream.

1.3 Context and Approach

Effective enforcement of TSW limits is critical to the realization of regulatory compliance and its impacts on safety, infrastructure, and industry competitiveness (Organisation for Economic Co-operation and Development (OECD) 2011; U.S. Department of Transportation 2000; Transportation Research Board (TRB) 1990). However, despite the widely held notion of a linkage between truck weight enforcement and compliance, there remains an inability to fully understand this relationship because of differences in how enforcement occurs and a lack of systematic and reliable evidence concerning overweight trucking (Carson 2011). Additionally, understanding this relationship for specific truck configurations—one of the main issues of interest in this 2014 CTSW Study—has generally been constrained by insufficient data.

Increasing investments in proven enforcement technologies, including tools for identifying non-compliant trucks or carriers and the expanded use of WIM devices for monitoring truck weights, provide some opportunity to address these historical data limitations (OECD 2011; Cambridge

Systematics 2009); however, certain data gaps persist, precluding a definitive analysis of the subject.

The analysis of costs and effectiveness undertaken in this study takes a performance-based approach. This approach considers enforcement program performance (or effectiveness) in terms of inputs, outputs, outcomes, and pertinent relationships between these measures. This performance-based approach extends the scope of analysis undertaken at the Federal level concerning TSW enforcement programs beyond what was considered in the previous *2000 Comprehensive Truck Size and Weight Study* (2000 CTSW Study) (see USDOT 2000). More recent research and development for enforcement programs at the State and national levels has advanced this approach and shaped the analysis undertaken in this 2014 CTSW Study (URS 2013; Fekpe et al. 2006; URS 2005; Hanscom 1998).

Enforcement program inputs reflect the resources available to carry out the TSW enforcement task. As shown in **Table 1**, the measures of input included in this study are program cost (disaggregated into costs for personnel and facilities) and the number and type of weigh scales used to enforce truck weights, including WIM sites used for screening truck weights.

Outputs reflect the way enforcement resources are used, the scale or scope of activities performed, and the efficiency of converting allocated resources into a product. Outputs help answer the question: what will or did we do with the resources given to us? As shown in **Table 1,** the measures of output used in this Report are the number of weighings, number of citations, number of vehicles required to shift loads or offload cargo to achieve compliance, and the number of permits issued for oversize/overweight (OS/OW) loads. While these outputs on their own provide some indication of program effectiveness, effectiveness can be further understood by relating certain program outputs and inputs. Three pertinent relationships are established, namely: the weighing cost-efficiency (weighings per personnel cost), the citation rate (citations per weighing), and the relationship between citation rate and enforcement intensity (measured as the number of weighings per truck vehicle-miles of travel (VMT)).

Outcomes reflect the degree of success of the TSW enforcement program in achieving its goals and objectives. Outcomes help answer the question: what will or did we achieve in relation to our purpose? From an operational and programmatic perspective, the goal of enforcement is to achieve compliance with TSW regulations. Success in achieving compliance ultimately improves safety, mitigates infrastructure deterioration, and promotes fairness and competitiveness within the trucking industry.

Table 1: Performance Measures Used in this Report

Type of Measure	Performance Measures
Input	• Enforcement program cost • Number of weigh scales by type • Number of WIM sites used for screening truck weights
Output	• Number of weighings • Citations • Number load shifting or offloading vehicles • Number of oversize/overweight permits issued

Type of Measure	Performance Measures
	• Weighing cost-efficiency • Citation rate • Citation rate as a function of enforcement intensity
Outcome	• Proportion of weight-compliant observations • Severity of overweight observations

The distinction between outputs and outcomes, while subtle, is important because measuring outputs may encourage efforts to increase certain output measures (e.g., the number of citations observed or reported), which should in fact decrease if enforcement achieves its overall goal of better compliance. In contrast, outcome-oriented measures may describe the proportion of compliant events (which may suggest successful enforcement) or the severity of overweight observations (which may suggest a lack of enforcement success). Conventional evaluations of enforcement programs have relied on outputs more than outcomes, presumably because outputs are easier to measure and monitor over time.

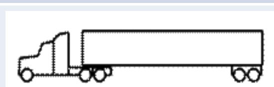
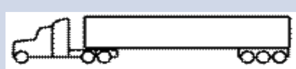
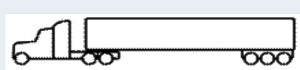
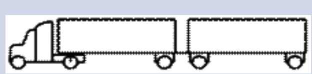
Applying the performance-based approach provides the supporting framework for a comparative analysis designed to reveal insights about the costs and effectiveness of TSW enforcement programs. Data limitations, consistency, and availability constrain a comprehensive, representative understanding of enforcement costs and effectiveness, particularly regarding vehicle-specific comparisons. To accommodate these limitations and leverage existing datasets and institutional knowledge, this study applies two types of comparisons.

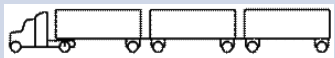
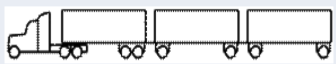
First, at the broader level, readily available, State-specific data provides the foundation for comparing costs and effectiveness between States that currently allow trucks above Federal weight limits and those that do not. As the state-level data used in these comparisons do not allow disaggregation by vehicle configuration, these comparisons can reveal potential vehicle-specific differences at a State level. Because of budget constraints, a subset of 29 States (referred to as comparison States) are used for this analysis. Based on recommendations by FHWA, the American Association of Highway Transportation Officials (AASHTO) Subcommittee on Highway Transport (SCOHT), and representatives from the Commercial Vehicle Safety Alliance (CVSA), the 29 States were selected because they: (1) are considered to be enforcement programming leaders in the nation; (2) have experience in enforcing vehicles subject to grandfather[1] provisions (e.g., longer combination vehicles); or (3) have recently undertaken research and development projects related to TSW enforcement. In addition, the selection of these States considered the need to represent general variations in trucking operations across the Nation (e.g., configurations in use, industries served) and geographic factors.

[1] The Federal government began regulating truck size and weight in 1956 when the National Interstate and Defense Highways Act (Public Law 84-627), establishing the Interstate Highway System, was enacted. A state wishing to allow trucks with sizes and weights greater than the Federal limits was permitted to establish "grandfather" rights by submitting requests for exemption to the FHWA. During the 1960s and 1970s, most grandfather issues related to interpreting State laws in effect in 1956 were addressed, and so most grandfather rights have been in place for many decades. See USDOT *Comprehensive Truck Size and Weight Study, Volume 2*, "Chapter 2: Truck Size and Weight Limits – Evolution and Context," FHWA-PL-00-029 (Washington, DC: FHWA, 2000), p. II-9.

Second, a more specific comparative analysis of enforcement program costs and effectiveness involves vehicle-specific comparisons (where possible). These comparisons focus on cost and effectiveness differences between the control vehicles and the six alternative truck configurations used in the six 2014 CTSW Study scenarios (**Table 2**). Thus, the results of the vehicle-specific comparisons directly support the scenario analysis, which estimates system-wide cost and effectiveness impacts that could result from the operation of the alternative truck configuration relative to the base case. In the cost analysis, the relevant performance measure is the cost of weighing the alternative truck configurations. In the effectiveness analysis, the relevant performance measures for assessing compliance are obtained for locations where representative data are available (principally WIM data). This assessment enables a quantitative analysis of certain compliance outcomes for the alternative truck configurations (such as the proportion of weight-compliant observations and the severity of overweight observations for specific truck configurations at that location). These compliance outcomes, however, cannot be directly related to enforcement activities to ascertain the effect of enforcement on these outcomes.

Table 2: Study Scenarios, Control Vehicles, and Alternative Truck Configurations

Scenario	Configuration	Depiction of Vehicle	# Trailers or Semi-trailers	# Axles	Gross Vehicle Weight (pounds)	Roadway Networks
Control Single	5-axle vehicle tractor, 53 foot semitrailer (3-S2)		1	5	80,000	STAA[1] vehicle; has broad mobility rights on entire Interstate System and National Net-work including a significant portion of the NHS
1	5-axle vehicle tractor, 53 foot semitrailer (3-S2)		1	5	88,000	Same as Above
2	6-axle vehicle tractor, 53 foot semitrailer (3-S3)		1	6	91,000	Same as Above
3	6-axle vehicle tractor, 53 foot semitrailer (3-S3)		1	6	97,000	Same as Above
Control Double	Tractor plus two 28 or 28 ½ foot trailers (2-S1-2)		2	5	80,000 maximum allowable weight 71,700 actual weight used for analysis[2]	Same as Above
4	Tractor plus twin 33 foot trailers (2-S1-2)		2	5	80,000	Same as Above

Scenario	Configuration	Depiction of Vehicle	# Trailers or Semi-trailers	# Axles	Gross Vehicle Weight (pounds)	Roadway Networks
5	Tractor plus three 28 or 28 ½ foot trailers (2-S1-2-2)		3	7	105,500	74,500 mile roadway system made up of the Interstate System, approved routes in 17 Western States allowing triples under ISTEA Freeze and certain four-lane PAS roads on East Coast[3]
6	Tractor plus three 28 or 28 ½ foot trailers (3-S2-2-2)		3	9	129,000	Same as Scenario 5[3]

[1] The STAA network is the National Network (NN) for the 3-S2 semitrailer (53') with an 80,000-lb. maximum GVW and the 2-S1-2 semitrailer/trailer (28.5') also with an 80,000 lbs. maximum GVW vehicles. The alternative truck configurations have the same access off the network as its control vehicle.

[2] The 80,000 pound weight reflects the applicable Federal gross vehicle weight limit; a 71,700 gross vehicle weight was used in the study based on empirical findings generated through an inspection of the weigh-in-motion data used in the study.

[3] The triple network is 74,454 miles, which includes the Interstate System, current Western States' triple network, and some four-lane highways (non-Interstate System) in the East. This network starts with the 2000 CTSW Study Triple Network and overlays the 2004 Western Uniformity Scenario Analysis, Triple Network in the Western States. There had been substantial stakeholder input on networks used in these previous USDOT studies and use of those provides a degree of consistency with the earlier studies. The triple configurations would have very limited access off this 74,454 mile network to reach terminals that are immediately adjacent to the triple network. It is assumed that the triple configurations would be used in LTL line-haul operations (terminal to terminal). The triple configurations would not have the same off network access as its control vehicle–2-S1-2, semitrailer/trailer (28.5'), 80,000 lbs. GVW. The 74,454 mile triple network includes: 23,993 mile network in the Western States (per the 2004 Western Uniformity Scenario Analysis, Triple Network), 50,461 miles in the Eastern States, and mileage in Western States that was not on the 2004 Western Uniformity Scenario Analysis, Triple Network but was in the 2000 CTSW Study, Triple Network (per the 2000 CTSW Study, Triple Network).

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CHAPTER 2 – COMPLIANCE ESTIMATION OF ENFORCEMENT COST

2.1 Scope

This chapter documents the results from the estimation of cost of enforcement analysis performed as part of this compliance study. The purpose of this study is to assess the cost of enforcing truck size and weight (TSW) limits for trucks currently operating at or below current Federal truck weight limits as compared with a set of alternative truck configurations in six scenarios. It also estimates the enforcement cost impacts of introducing the alternative truck configurations into the traffic stream. To accomplish this, the objectives of the work are to:

- Document steps and procedures for the principal TSW enforcement methods used in North America, including the application and costs of technological components and systems;
- Gather and analyze truck enforcement program costs and resources (referred to as program inputs) at a national scale;
- Compare truck size and weight enforcement costs for States where trucks are authorized to operate above Federal limits with similar costs for States that adopt Federal truck weight limits; and
- Determine and compare the costs of weighing the alternative truck configurations and estimate the scenario cost impacts.

The scope of analysis for this work is constrained as follows:

- The base analysis year for the study is 2011. To capture annual trends in enforcement program costs, the analysis examines data reflecting program resources and activities from 2008 through 2012, inclusive, thereby using the most current, reliable data available.
- While the work focuses on TSW enforcement costs, much of the available cost data reflects the allocation of resources for both TSW and commercial vehicle safety enforcement. The costs reported by States reflect resources (e.g., personnel, facilities) directed at TSW enforcement and truck safety enforcement. No attempt has been made to disaggregate costs allocated to these separate programs.
- This work analyzes resources directed at enforcing truck size and weight. However, to support the purpose of this work, certain aspects of the analysis focus solely on truck weight.
- The work supports the comparative analysis of commercial motor vehicles that operate at or below an 80,000 lb. gross vehicle weight, a 20,000 lb. single-axle weight; a 34,000 lb. tandem axle weight ,and at or below weight limits as calculated through the Federal Bridge Formula as such limits are provided in Title 23 of the United States Code under Section 127. Per the legislation, vehicles that are exempted from the size and weight limits stated and provided in 23 USC Section 127 are to be treated as "vehicles operating in excess of federal size and weight limits." Vehicles operating under a State-issued

permit, including all divisible or non-divisible load movements, are to be treated in the same manner.

2.2 Methodology

As described in **Chapter 1**, enforcement program costs are considered inputs in the performance-based approach applied in this study. Within the context of this approach, this section provides specific details about the methodology and data applied for three of the four objectives. The methodology applied in this work extends the results of the previous 2000 CTSW Study in three main ways:

- It provides an updated and more comprehensive description of TSW enforcement methods and technologies. (The methodology used to achieve this objective is relatively straightforward, so no details are provided here.)
- It provides a more detailed analysis of the costs of enforcement at the national level, including an investigation of recent cost trends.
- It includes a comparative analysis of how costs may be impacted by the introduction of alternative truck configurations into the traffic stream. This type of analysis was not conducted as part of the previous 2000 CTSW Study.

National-Level Trends

The measures of input included in the analysis of national-level trends are program cost (disaggregated into costs for personnel and facilities) and the number and type of weigh scales used to enforce truck weights, including WIM sites used for screening truck weights. State Enforcement Plans (SEPs),which are submitted annually by States to the FHWA, provide the primary source data for the analysis of enforcement costs and resources. The USDOT study team analyzed tabulated summaries for key metrics from 2008 to 2012 (i.e., total costs, facilities costs, personnel costs, quantity of weigh scale equipment). The following limitations apply to the data:

- The costs reported in the SEPs reflect those costs for truck size, weight, and safety enforcement. In most States, these programs overlap considerably—both personnel and facilities resources may be used to enforce size and weight limits and conduct vehicle safety inspections—and so no attempt was made to disaggregate costs allocated to these separate programs.
- The costs reported in the SEPs reflect those costs deemed by the State to be directed at enforcement activities in that State each year. For the most part, specific States show consistent cost trends over time; however, costs for certain States exhibit anomalies when major capital expenditures (e.g., for new enforcement facilities) are undertaken in a particular year.
- The SEPs do not contain any systematically reported information about TSW enforcement costs for specific vehicle configurations, routes, networks, industries, commodities, or permitted versus non-permitted trucks.

- It appears that certain States may be reporting the actual number of portable scales in operation while others may be reporting the number of locations at which portable scales are used or even the number of weighings conducted with portable scales.

State-Level Comparative Analysis

This component of the analysis in this work compares the enforcement costs and resources (i.e., weigh scales) for States that allow vehicles in excess of Federal truck weight limits (i.e., above-limit States) and States that do not allow vehicles in excess of Federal limits (i.e., at-limit States). The comparisons aim to identify state-level differences in enforcement costs and resources, and can be understood as a surrogate way of revealing potential vehicle-specific differences. The designation of the States as “at limit” and “above limit” considers three information sources:

- Relevant TSW regulations pertaining to single-semitrailer and multiple trailer trucks operating in each State (e.g., the U.S. Code of Federal Regulations, Title 23, Part 658, Appendix C) provide one indication about whether a State may be effectively at-limit or above-limit. For example, States that routinely permit triple trailer combinations on Interstate highways may be designated as above-limit States.
- Estimated 2011 vehicle miles travelled (VMT) for the scenarios’ alternative truck configurations (e.g., six-axle tractor semitrailers, triple trailer combinations) provide an indication of the extent of operation of above-limit trucks in a State by highway network type. For example, States where six-axle semitrailers commonly operate above 80,000 lb. GVW (other than those where a single-trip permit may be required) may be designated as above-limit.
- Insights from commercial motor vehicle State enforcement officials provide an experiential indication of whether a State may be designated as at limit or above limit.

As such, these comparisons do not account for State-specific variations in enforcement program delivery and permitting activities, nor do they fully consider the extent to which each truck configuration is allowed to operate within a State. Nevertheless, the comparisons provide one pragmatic approach for identifying potential cost differences associated with enforcing different types of truck configurations.

The scope of the comparative analysis includes the 29 comparison States. States included in each of these groups are listed in **Table 3: States Included in Comparative Analysis.** Based on these information sources for the purpose of this comparative analysis, 13 of the 29 comparison States are designated as at-limit and 16 as above-limit. As indicated earlier, the 29 comparison States were selected because they: (1) are considered to be enforcement programming leaders in the Nation, (2) have experience in enforcing vehicles subject to grandfather provisions (e.g., longer combination vehicles), or (3) have recently undertaken research and development projects related to TSW enforcement. In addition, the selection of these States addressed the need to represent general variations in trucking operations across the Nation (e.g., configurations in use, industries served) and geographic factors.

Table 3: States Included in Comparative Analysis

Federal States (at-limit)
Alabama
Arizona
Arkansas
Florida
Georgia
Illinois
Kentucky
Maryland
Minnesota
North Carolina
Texas
Virginia
Wisconsin
Non-Federal States (above-limit)
Alaska
Colorado
Idaho
Kansas
Maine
Michigan
Missouri
Nevada
New Mexico
New York
Ohio
Oklahoma
Oregon
Utah
Vermont
Washington

The comparative analysis focuses on costs reported for 2011 only. To help account for differences in the relative size of the TSW enforcement task in different States, all costs are normalized using 2011 estimates of truck VMT in that State. The truck VMT estimates include all single-unit trucks, single-semitrailer trucks, and multiple-trailer trucks. To reduce the impact of outlying data points, the comparison uses ranges and median values to compare costs and resources available for TSW enforcement in at-limit and above-limit States.

Truck Weight Enforcement Cost Comparisons for the Alternative Truck Configurations

The final component of the analyses in this work compares the costs associated with enforcing truck weights for the study scenarios' alternative truck configurations relative to the control vehicles (as specified in the scenarios). As no publicly available systematic data source exists to support such analysis, information about the time required to weigh various truck configurations was gathered from seven commercial motor vehicle State enforcement officials. This information is used as the basis for estimating truck weight enforcement costs for the scenario analysis. These officials were part of a Working Group of representatives from the Commercial Vehicle Safety Alliance; this group assisted with various aspects of the Study by providing experienced-based insights. The Working Group's membership included people in leadership positions within the CVSA community and featured several decades of experience in conducting truck size and weight enforcement program activities. All seven weighing time estimates received from the Working Group were included in the analysis. These estimates were obtained from: Arizona, Arkansas, Maryland, Michigan, North Carolina, Oklahoma, and Texas. **Appendix E** contains the instructions to participants and the form used to collect these data.

The time required to conduct a weighing may vary by the truck configuration being weighed and the type of weigh scale being used. State enforcement officials provided weighing times for the six alternative truck configurations and the two control vehicles being studied. The control vehicles, commonly referred to as Surface Transportation Assistance Act (STAA) vehicles, are:

- A five-axle tractor semitrailer at 80,000 lb. GVW with a 53-ft. semitrailer; and
- A five-axle tractor semitrailer-trailer at 80,000 lb. GVW[2] with one 28.5-ft. semitrailer and one 28.5-ft. trailer.

Three alternative truck configurations are compared to the five-axle tractor semitrailer control vehicle. These are:

- The five-axle tractor semitrailer at 88,000 lb. GVW with a 53-ft. semitrailer;
- The six-axle tractor semitrailer at 91,000 lb. GVW with a 53-ft. semitrailer; and
- The six-axle tractor semitrailer at 97,000 lb. GVW with a 53-ft. semitrailer.

The remaining three alternative truck configurations are compared to the five-axle tractor semitrailer-trailer (2-S1-2) control vehicle. These are:

- The five-axle tractor semitrailer-trailer at 80,000 lb. GVW one 33-ft. semitrailer and one 33-ft. trailer;
- The seven-axle tractor semitrailer-trailer-trailer at 105,500 lb. GVW with a 28.5-ft. semitrailer and two 28.5-ft. trailers; and

[2] The 80,000 pound weight reflects the applicable Federal gross vehicle weight limit; a 71,700 gross vehicle weight was used in this study based on empirical findings generated through an inspection of actual weigh-in-motion data.

- The nine-axle tractor semitrailer-trailer-trailer at 129,000 lb. GVW with a 28.5-ft. semitrailer and two 28.5-ft. trailers.

For each of these truck configurations, weighing times were provided for the four main types of weigh scales: fixed static scales (including scales that weigh axle groupings and weigh bridges that weigh the whole vehicle at once), portable scales, semi-portable scales, and WIM scales (including the use of a WIM at a virtual weigh scale).

The following nine-step procedure was developed for estimating the system-wide enforcement cost impacts for each of the six scenarios. The analysis estimates the percentage change in personnel costs that could occur nationwide as a result of the traffic conditions specified by each scenario.

1. Determine the proportion of VMT by truck configuration in each State for the base case defined in this Study.
2. For the base case in each State, distribute the non-WIM weighings for each scale type (i.e., weighings using fixed static scales, semi-portable scales, and portable scales) according to the VMT proportions calculated in Step 1. This calculation assumes that all static weighings are conducted using scales that weigh axle groups independently, since: (1) there is no incremental weighing time associated with the alternative truck configuration when using a static weigh bridge (as is the case for single-semitrailer trucks), or (2) incremental weighing times are irrelevant if the length of the weigh bridge cannot accommodate the length of the alternative truck configuration (as may be the case for triple trailer combinations).
3. Calculate base case weighing rates (i.e., the number of weighings per VMT) by State, truck configuration, and weigh scale type. These weighing rates are held constant in this analysis.
4. Determine incremental weighing time factors for each truck configuration and scale type relative to the time it takes to weigh a five-axle tractor semitrailer (control vehicle) on a fixed (axle group) weigh scale. For example, according commercial motor vehicle State enforcement officials, on average, it takes about 17 minutes to weigh a six-axle tractor semitrailer using a semi-portable scale, compared to about four minutes to weigh a five-axle tractor semitrailer using a fixed (axle group) weigh scale. Therefore, the incremental weighing time factor for this comparison is 4.25 (17 divided by 4). It is assumed that the incremental time factors calculated in this way are equal to incremental personnel cost factors.
5. Using the total personnel costs for each State and the incremental personnel cost factors determined in Step 4, develop an equation that can be solved to determine the average cost of weighing a five-axle tractor semitrailer (control vehicle) on a fixed (axle group) scale. This average cost is held constant in this analysis.
6. In each State, multiply the new scenario VMT estimates for each vehicle configuration by the weighing rates calculated in Step 3 to determine the number of weighings by truck configuration and scale type for the scenario.
7. Multiply the number of weighings for each truck configuration and scale type by the incremental personnel cost factors (for each truck configuration and scale type)

determined in Step 4. The sum of these costs is the total personnel cost in each State under the scenario traffic conditions.

8. Sum up the total personnel costs in each State determined in Step 7 for the scenario and compare these totals to the base case total personnel costs to determine the system-wide impacts of the scenario on personnel costs.

9. Repeat Steps 6 to 8 for each scenario.

2.3 Results

This section summarizes steps and procedures for the principal TSW enforcement methods used in North America, including the application and costs of technological components and systems used to enforce truck weights. It also summarizes national-level truck weight enforcement program costs and resources (such as weigh scales) used to accomplish the enforcement task. The analysis based on this data provides information at the national level in addition to state-specific cost and resource trends (specific State names are withheld). This section also compares the enforcement costs for States that allow vehicles in excess of Federal limits and States that effectively do not allow vehicles in excess of Federal limits. Data from the subset of 29 comparison States supports this analysis. Finally, this section compares the costs of weighing the alternative truck configurations identified for the scenario analysis. By applying the nine-step procedure described in the foregoing section, the analysis also estimates the percentage change in personnel costs that could occur nationwide as a result of the traffic conditions specified by each scenario. It also estimates the enforcement cost impacts at a system-wide level for each of the six scenarios.

Principal TSW Enforcement Methods and Technologies

Technology Components

Technologies play an important role in TSW enforcement. In light of current truck travel demand levels, the resources available for TSW enforcement, and the support of ongoing research being conducted by the FHWA and the Federal Motor Carrier Safety Administration (FMCSA), technologies designed to automate enforcement activities are becoming increasingly popular with State enforcement agencies. Some technologies work well alone while others are more effective when used as a component in a broader technology system. The technologies presented in this sub-section are the components that serve as the building blocks for enforcement technology systems.

There is a subset of technologies that solely measure vehicle or axle weights for the purpose of weight enforcement. This subset (fixed static scales, semi-portable scales, and portable scales), becomes much more effective when deployed in a system-based enforcement approach. For example, when the time required to use one of these basic weighing technologies to weigh a passing truck exceeds the arrival rate of trucks required to be weighed, a more systematic approach should be considered to increase enforcement resource efficiency.

Static Scales

Source: Richard Easley

A static scale is a permanently fixed mechanism that is used to weigh trucks with a precision and accuracy that is suitable for issuing overweight vehicle or axle citations. The static scales require regular calibration services for certification purposes to maintain accuracy. They are typically used at weigh stations as well as private sector locations. Weigh station applications are key for weight enforcement, while private sector static scale locations are necessary for weight certification of vehicles and cargo, and are typically used for payment verification purposes by private sector businesses.

Static scale deployment at weigh stations provides the data necessary to identify those motor carriers that may be operating illegally (overweight without a permit). Enforcement officers sometimes use static scales to weigh vehicles that were flagged by other means (as potentially overweight) at locations in the vicinity of a weigh station. The enforcement personnel accompany the vehicle in question to the weigh station to verify the vehicle (or one or more of its axle configurations) is actually overweight and can then issue a legally enforceable citation based on the data generated by the static scale. The static scale can be used to measure the weight of the entire vehicle or it can measure axle groupings independently.

Source: Richard Easley

Approximate Cost:

The cost of static scales includes the necessary construction to support the in-ground equipment as well as the maintenance costs and periodic Weights and Measures certifications to ensure accuracy. Prices for static scales can range from $100,000 to $200,000 (Hanson, 2014). The size of the scale varies as does the pricing. Annual maintenance costs range from $9,000 to $18,000.

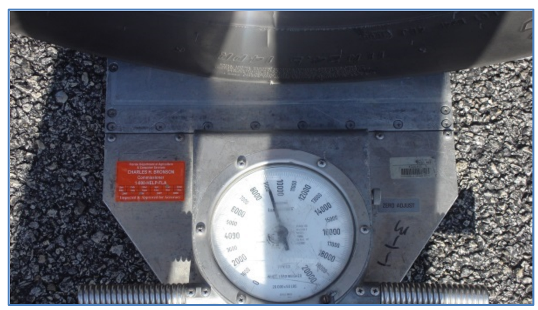
Portable Scales

Source: Richard Easley

Portable scales are pieces of equipment that can be transported in the enforcement officer's vehicle and can be used on the roadside to weigh a truck. The accuracy level of portable scales is considered legally acceptable for issuing overweight citations. Portable scales are only used for individual vehicle axles; a scale is used for each side of the axle to obtain total axle weight (the measured weight of the right side of the axle is added to the measured weight of the left side of the axle to obtain a total axle weight). The enforcement officer typically places the portable scale in front of the tires of the axle to be weighed and then asks the commercial vehicle driver to roll forward and stop on top of the scale. This is done for each axle to obtain total vehicle weight as well as individual axle weights. While a truck's total weight may not exceed the maximum allowable to operate on the roadway, it is possible that one particular axle on the truck may exceed the legal axle weight limit. A truck can be cited for exceeding the total weight or exceeding individual axle weight limits. In dangerous conditions the enforcement officer may request that, in lieu of using the portable scales, the driver follow the officer to the nearest weigh station where static scales can be used.

Approximate Cost:

Portable scale prices vary and can cost between $2,000 and $4,700 per device (Hanson, 2014). Enforcement personnel typically have four portable scales per patrol vehicle and each scale must be calibrated and certified at periodic intervals to ensure their accuracy and legality. Annual maintenance costs range from $180 to $425 and include scale recertification costs.



Source: Aaron Van Heel

Semi-Portable Scales

Semi-portable scales (also referred to as axle scales) are larger than portable scales, and various States use them for weight enforcement details that are temporary in nature and that can benefit from this technology, which allows for much shorter weighing times than portable scales. Semi-portable scales are suitable for issuing citations – which means they satisfy legal certification requirements. While they are cumbersome to move around (relative to transporting portable scales) and require special equipment (a trailer), they are sometimes preferred for temporary enforcement sites due to their ability to measure axle weights and total vehicle weights without the need to place individual portable scales in front of each wheel and then have the driver roll forward and stop on top of them.

Source: Aaron Van Heel

Semi-portable scales allow the enforcement officer to tell the commercial vehicle driver to drive on top of the scales and stop. The officer can then record the axle weights before allowing the driver to drive forward – to be followed by the next commercial vehicle. There is no need to move the scales during this process.

Approximate Cost:

Semi-portable scale prices vary and can cost between $10,000 and $59,000 (Arizona DOT) per set. The accompanying trailer has a typical cost of approximately $10,000 (Van Heel, 2014). Annual maintenance costs for the system range from $900 to $5,300. As with portable scales, semi-portable scales must be calibrated and certified for accuracy at periodic intervals.

<u>Weigh-in-Motion Systems</u>

Weigh-in-motion (WIM) systems vary in appearance, cost, and accuracy. While the different technologies have their unique characteristics, all WIM systems perform the function of weighing vehicles without requiring them to stop. Some of the most popular WIM systems can be classified as:

- Piezoelectric
- Piezoquartz (Kistler)
- Bending Plate
- Single Load Cell

These systems can be placed on mainline roadways, entrance and exit ramps, city streets, and even in parking lots. Their primary value is to allow vehicles to be weighed without requiring commercial vehicle traffic to come to a complete stop. Different systems have different operating characteristics. Some WIM systems are effective at highway speeds while others are more accurate at lower speeds (0-12 MPH/0-20 KPH).

Typically, WIM systems are used as screening or sorting devices to eliminate the need to stop and weigh every truck while in transit. While WIM systems have proven to be valuable screening tools when working properly, they are not yet approved by U.S. Courts as legally acceptable for directly issuing overweight citations in the United States. When a WIM system identifies a commercial vehicle as being overweight, the enforcement officer must conduct a follow-up weighing using portable, semi-portable scales or a static scale as these are the only legal weighing systems that can be used as the basis for issuing a citation.

In addition to their use as a screening tool, WIM systems are able to store the data collected at unmanned sites for later analysis to determine commercial vehicle violation patterns and employ intelligent enforcement details. This type of data can also be used for planning purposes to determine pavement loadings experienced on roadways throughout the network. In the United States, quite often locations where WIM is installed was decided by non-truck weight enforcement purposes. Pavement engineers have used WIM for many years supporting their research programs. WIM is also installed by the states for traffic monitoring purposes that support planning activities and, hence, do not always coincide with the strategic locations required for truck weight enforcement purposes.

In terms of data availability, depending upon the system configuration, some WIM data is retrievable over the Internet and can be viewed in the home office or in manned field stations (PBS&J, 2008, pp. 4-11).

Piezoelectric Weigh-in-Motion

The basic construction of the typical piezoelectric WIM sensor consists of a copper strand surrounded by piezoelectric material, which is covered by a copper sheath. When pressure is applied to the piezoelectric material, an electrical charge is produced. The sensor is actually embedded in the pavement and the load is transferred through the pavement. The characteristics of the pavement (level approach, temperature, etc.) will therefore affect the output signal. By measuring and analyzing the charge produced, the sensor can be used to measure the weight of a passing tire or axle group.

Source: International Road Dynamics Inc.

For a complete data collection system, it is common to install two inductive loops and two piezoelectric sensors in each lane that is being monitored. Installation begins with making a relatively small saw cut in the road into which the sensor is installed. The size of the cut varies depending on the sensor being installed, but is generally 1” to 2” deep and 1” to 2” wide. The sensor is placed in the cut and secured in place by a fast-curing grout. A complete lane installation consisting of two sensors and two loops can be accomplished in less than a full day, including curing time.

When properly installed and calibrated, a piezoelectric WIM system should be expected to provide gross vehicle weights that are within 15 percent of the actual vehicle weight for 95 percent of the trucks measured.

Two of the advantages of this technology are that the costs are low and the technology is accepted and widely utilized. Another advantage is the minimal traffic disruption during installation.

The disadvantages, however, include inadequate precision for vehicle weight accuracy (loads can vary by as much as ±15 percent). While this technology can be used for distinguishing between loaded or empty trucks, it is not precise enough to be used for accurate screening of loaded trucks to determine which ones are overweight. In addition, this technology is highly susceptible to pavement perturbations. Equipment lifespans are shorter than some of the more expensive WIM technologies, with the piezoelectric system having a lifespan of approximately 4 years; further, pavement life affects the technology’s longevity.

Approximate Cost:

The piezoelectric system offers the lowest capital cost, the lowest cost to install and is suitable for data collection applications (low accuracy) (PBS&J, 2008, pp. 4-11).

While the initial costs for this technology are low, the necessary maintenance and calibration expenses can be considerable. The equipment cost, including electronics, for one lane is approximately $10,000 - $15,000. The total installed cost for one lane is between $25,000 and $30,000 excluding communications or traffic control costs. Tieing in additional installations within lanes at the same site cost approximately $3,500. Annual maintenance costs range from $2,250 to $2,700.

<u>Piezoquartz (Kistler) Weigh-in-Motion System</u>

The piezoquarts or Kistler WIM system consists of a light metal profile in the middle of which quartz disks are fitted under preload. When force is applied to the sensor surface the quartz disks yield an electric charge proportional to the applied force through the piezoelectric effect. A charge amplifier converts this electric charge into a proportional voltage, which can then be further processed as required.

The sensors can be installed in combination with other traffic detectors like induction loops, switching cables, etc. Compared to other weight enforcement technologies, Kistler WIM sensors are relatively easy to install both individually and in groups for comprehensive recording over a wide roadway.

Installation begins by making a relatively small saw-cut in the road into which the sensor will be installed. The size of the cut varies depending on the sensor being installed, but is generally 2.25” deep and 3” wide. The sensor is placed in the cut and secured by a fast-curing grout. A complete lane installation consisting of eight sensors and two loops can be completed in less than a day, including curing time. When properly installed and calibrated, the Kistler WIM system should be expected to provide gross vehicle weights that are within 10 percent of the actual vehicle weight for 95 percent of the trucks measured.

Source: Richard Easley

Kistler WIM is a relatively new technology that provides suitable screening accuracy. The cost, while slightly more expensive than piezoelectric, still requires relatively little disruption of traffic for installation. Kistler WIM, as with many other WIM technologies, is not precise enough to issue a citation. This technology's accuracy is also susceptible to pavement conditions (weather, rutting, plow damage, etc.) Additionally, an equipment lifespan of approximately 6 years is shorter than some of the more expensive WIM technologies (PBS&J, 2008, pp. 4-11).

Approximate Cost:

While the initial costs for this technology are low, the necessary maintenance and calibration expenses can be considerable. Equipment cost including electronics for one lane is approximately $25,000 to $30,000. The total installed cost for one lane is between $45,000 and $60,000 and does not include communications costs or traffic control costs. Installations in additional lanes at the same site cost between $15,000 and $18,000 (Hanson, 2014). Annual maintenance costs range from $4,100 to $5,400.

<u>Bending Plate Weigh-in-Motion</u>

Source: International Road Dynamics Inc.

The Bending Plate scale consists of two steel platforms, which are each 2' by 6', placed adjacent to each other to cover a 12' lane. The steel plate is instrumented with strain gauges at critical points to measure the pressure in the plate as a tire or axle passes over. The measured strain is analyzed to determine the axle load. The Bending Plate scale is typically installed in a lane with two inductive loops and an axle sensor to provide vehicle length and axle spacing information.

There are two basic installation methods for a Bending Plate scale. In concrete roadways of sufficient depth, a shallow excavation is made in the surface of the road (Quick Installation). The scale frame is anchored into place using anchoring bars and epoxy. In asphalt roads or thin concrete roads, it is necessary to install a concrete foundation for support of the frame (Vault Installation). The roadway is cut and excavated to form a pit of 30" deep by 4'10" wide by 13'10" long. Then, the frame is positioned in place and cast into concrete to form a secure and durable foundation for the scale.

Source: International Road Dynamics, Inc.

Installing a complete lane of scales, loops and an axle sensor can be accomplished in less than a day using the shallow excavation method and in 3 days using the concrete vault.

When properly installed and calibrated, the Bending Plate WIM system should be expected to provide gross vehicle weights that are within 10 percent of the actual vehicle weight for 95 percent of the trucks measured.

Bending Plate WIM is a much more robust WIM technology than the piezo systems described earlier. This system is capable of withstanding weather extremes, but if incorrectly installed it can create substantially more severe consequences to the traveling public. The labor and the traffic disruption necessary to install this system are slightly greater than the piezo approaches, and the accuracy is not much better considering the additional costs. The Bending Plate system has a lifespan up to twice as long as the piezoelectric-based approaches (PBS&J, 2008, pp. 4-11).

Approximate Cost:

The costs for this technology are 'moderate' and the necessary maintenance and calibration expenses can be considerable. Equipment cost including electronics for one lane is approximately $25,000 - $32,500. The total installed cost for one lane is between $55,000 and $65,000 excluding communications or traffic control costs (Hanson, 2014). Installations at additional lanes at the same site cost between $15,000 and $20,000. Annual maintenance costs range from $5,000 to $5,900.

<u>Single Load Cell Weigh-in-Motion</u>

The Single Load Cell Scale consists of two weighing platforms with a surface size of 6' by 3'2" placed adjacent to each other to fully cover a normal 12' traffic lane. A single hydraulic load cell is installed at the center of each platform to measure the force applied to the scales. The load measurements are recorded and analyzed by the system electronics to determine the axle loads.

Source: International Road Dynamics, Inc.

The installation of a single load cell scale requires the use of a concrete vault. The roadway is cut and excavated to form a pit. The frame is positioned in place and then cast into the concrete to form a secure and durable foundation for the scale. The size of the vault required measures 165" by 58" by 38". The Single Load Cell scale is typically installed in a lane with two inductive loops and an axle sensor to provide vehicle length and axle spacing information. A complete installation of scales, loops, and axle sensor in a single lane can be accomplished in 3 to 4 days.

Source: International Road Dynamics, Inc.

When properly installed and calibrated, the Single Load Cell WIM system should be expected to provide gross vehicle weights that are within 6 percent of the actual vehicle weight for 95 percent of the trucks measured.

Single Load Cell WIM is a more accurate WIM technology than the WIM systems described earlier. This system is capable of withstanding weather extremes, but incorrect installation consequences are substantially more severe to the traveling public. According to a FHWA study result (USDOT, FHWA, 2014a, p. 5), the Single Load Cell WIM has an accuracy level of ± 6 percent and with proper calibration and maintenance, is considered the highest among the WIM systems investigated (PBS&J, 2008, pp. 4-11).

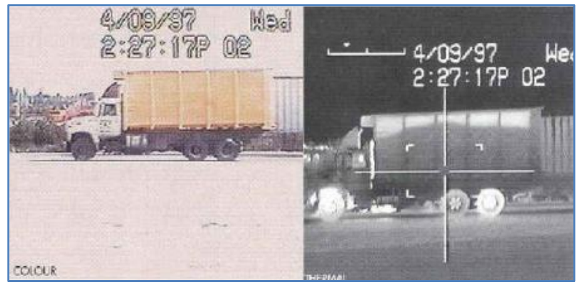
Approximate Cost:

The costs for this technology and the necessary maintenance and calibration expenses can be considerable; however, these are offset by the extended lifespan of the system. The equipment cost including electronics for one lane is approximately $70,000 to $90,000. The total installed cost for one lane is between $100,000 and $150,000 excluding communications or traffic control costs (Hanson, 2014). Annual maintenance costs range between $12,600 and $16,200.

Source: International Road Dynamics, Inc.

It is important to note that the useful lifespan of the single load cell WIM is considerably longer than some other WIM systems, making total lifecycle costs and increased accuracy a consideration. The actual service life of a properly installed and maintained load cell site has not been estimated since load cell technology usefulness is impacted by the condition of adjacent pavement. Well-maintained surrounding pavement can yield a considerable load cell service life. Conversely, poorly maintained pavement can reduce the load cell service life due to damage caused by a non-smooth interface between the load cell and surrounding pavement.

Thermal Imaging



Source: Infrared Inspection System (IRIS)

Thermal imaging technology is a highly innovative screening tool. Many States are using this technology, which qualifies for Motor Carrier Safety Assistance Program (MCSAP) funding. What makes thermal imaging unique is that it can screen trucks, cars and even buses while they travel at normal speeds. The primary purpose for this technology is to check brakes – the single most frequent form of equipment failure responsible for placing commercial vehicles out of service. An ancillary benefit of thermal imaging is its ability to detect overloaded vehicles through the heat signature of the tires. Experienced enforcement officers have long known that overloaded tires produce large amounts of heat, which is visible to thermal imaging technology.


Source: Richard Easley

Because an infrared scanner is able to measure heat, when vehicles drive along a flat grade and the brakes are not in use, the technology can detect possible brake problems. If any of the wheels measure "hot" or appear bright on the enforcement official's display, then there is a strong possibility that this particular brake is malfunctioning. Conversely, if a truck is coming to a stop and is using the brakes, all the wheels should measure "hot" or bright on the infrared monitor. If any of the wheels are "cool" or appear dark, then those particular wheels do not have properly functioning brakes. In either case, the thermal imaging serves as a good screening tool to select vehicles for more in-depth brake inspection.

Thermal imaging technology is deployed in multiple ways:

- Hand-held devices require an enforcement officer to merely point the device at the tires as the vehicle drives by or is stopped.
- Van-mounted devices allow the enforcement officer to sit inside the van and remotely aim the infrared device at trucks to view heat signatures.
- Devices installed at roadside (at wheel level) capture heat signatures for each truck passing the equipment.
- Devices installed beneath the pavement in the middle of a lane captures a heat signature for each wheel/brake/axle as the truck rolls over the device.


Source: Washington State Department of Transportation and Sharon Easley

Enforcement personnel can use this thermal imaging data to select potentially unsafe (or overweight) trucks to intercept, inspect, and, if warranted, remove the unsafe or overweight vehicles from the roadway.

Approximate Cost:

The costs for thermal imaging technologies can vary.

- Hand-held units can cost between $6,000 and $10,000, depending upon the unit.
- Roving vans fully equipped with thermal imaging systems can cost approximately $300,000.
- Roadside-mounted thermal imaging technology can cost approximately $150,000.
- Subsurface thermal imaging technology can cost approximately $250,000 and has the added cost of roadway construction (Taylor, 2014).

Maintenance costs for these technologies vary depending upon the type of system used. Handheld maintenance costs can range from $540 to $900, and mobile van systems maintenance costs are approximately $27,000 per year. Roadside fixed system maintenance costs are $13,500 and subsurface mounted system maintenance costs can reach $22,500 per year.

<u>Height Detection System</u>

Source: Richard Easley

A height detection system will consist of a laser detector or optical sensor which points across the roadway at a certain height and includes a method of communication to alert the driver, or enforcement personnel, when a vehicle exceeding an pre-determined height drives past. When a vehicle breaks the laser beam, it can trigger a series of safety measures including warning the driver, providing the driver with an alternate and safe diversion, or alerting motor carrier enforcement that a triggering event has occurred. While there are no height restrictions in Federal law or regulation, most States impose enforceable State height limits ranging from 13.6 feet to 14.6 feet (USDOT, FHWA, 2014b).

Height detection systems can be valuable in areas with low overpasses or where tunnels are present. In addition, these systems can prove valuable in areas where accidents related to high winds regularly occur, such as on bridges. With respect to size and weight enforcement, when this technology is deployed near a weigh station, any triggered events can alert enforcement personnel to check for the proper permits or issue citations if the proper permits have not been purchased (i.e., the oversized vehicle is not operating legally).

Approximate Cost:

The cost to furnish and install the two poles, light source, optical sensor and associated equipment is approximately $30,000 (Hanson, 2014). Yearly maintenance costs are approximately $2,700.

<u>Three Dimensional Measuring Systems</u>

Source: Richard Easley

Three dimensioning (3D) technology is one of the tools used to measure a vehicle's width, height, and length. By scanning the vehicle as it passes the reader, an image is processed and analyzed. This data is then converted into the vehicle's dimensions.

There are several approaches to obtaining 3D imaging, which can include side readers as well as overhead readers, as image accuracy is sensitive to laser reader installation angle. While this technology cannot determine a vehicle's weight for enforcement purposes, it can identify those commercial vehicles that exceed legal width restrictions. As noted previously, while there are no Federal height restrictions, most States impose enforceable State height limits ranging from 13.6 feet to 14.6 feet (USDOT, FHWA, 2014b).

Source: Richard Easley

To date this technology is not approved for citation issuance purposes, but is an efficient screening and data collection tool.

Approximate Cost:

Costs for 3D systems vary; the furnish and install price is estimated at $235,000 (Hanson, 2014). Annual maintenance costs for these systems are estimated at $21,200.

<u>Closed Circuit Television (CCTV) Systems</u>

Closed Circuit Television (CCTV) cameras and more advanced video image detection systems are relatively inexpensive technologies that can monitor truck activity on weigh station bypass routes. Video image detection systems use machine vision technology to compile and analyze traffic data collected with CCTV systems. Video image detection can automatically monitor freeway conditions, capture speeds, and count and classify vehicles.

Source: Florida Department of Transportation

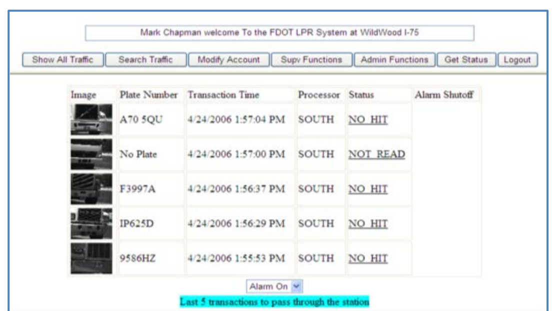
There are many benefits to CCTV deployment including the ability to "see" commercial vehicle traffic on remote roadways, on major thoroughfares, or any location that can be viewed from the public right-of-way. These traffic images can be viewed in real-time or the images can be stored and viewed at a later date. An added benefit is that the CCTV data can be viewed from anywhere with Internet access and by any enforcement personnel with the appropriate access permissions.

Using CCTV Cameras to monitor bypass routes can provide true counts of commercial vehicles, and limited truck body type information (e.g., logging trucks, car carriers, tanker trucks, etc.) can be collected. Today there are many cameras in use that capture images of vehicles as they are detected (by various types of sensor technologies) when certain sensor criteria are met. For example, sensors can activate CCTV cameras when a specific classification of vehicle is detected, a weight threshold is exceeded, speeds are exceeded, etc. This is helpful for enforcement when a vehicle is determined to be overloaded, over-height, or over-length. The CCTV image can be used to identify the vehicle by an enforcement officer in the immediate vicinity or for analysis at a later date.

Approximate Cost:

The cost for this technology ranges from $10,000 to $50,000 for a color CCTV camera, and annual maintenance costs range from $200 to $1,000 (Hanson, 2014). This assumes an existing communications link and does not include the software systems and algorithms for automated surveillance.

<u>License Plate Recognition</u>

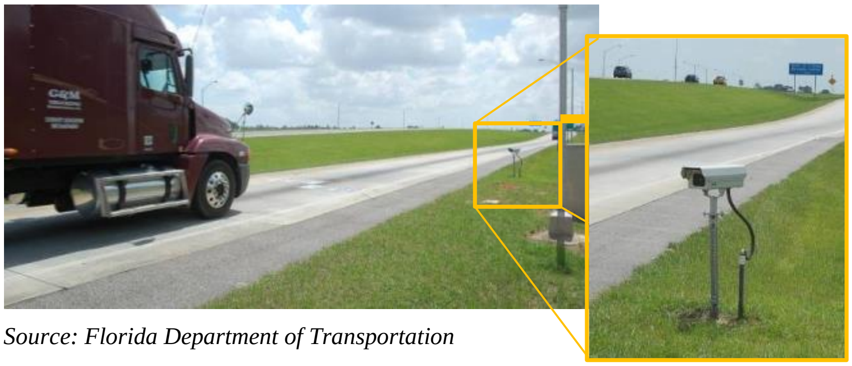


Source: Florida Department of Transportation

License plate reader (LPR) technology is the application of a camera and sophisticated software (optical character recognition (OCR)) which takes the image of a license plate and converts that image to alpha-numeric characters. This license plate information can be stored in a database or the software can perform a "look up" for a matching license plate in a database that may contain stolen tags, Amber Alert information associated with a tag or other information. Applications can include such simple "look ups" as identifying truck license plates that regularly use a bypass route.

LPR technology can be used in daylight as well as nighttime using various lighting techniques including infrared lighting, Xenon lighting, light-emitting diode (LED) lighting, etc.

LPR technology can be used on virtually any truck with a license plate—in other words, all of them, since every commercial vehicle has to mount a license plate in order to operate legally on US roadways. In addition, the technology does not require any additional equipment to be installed on the truck – such as a transponder. The camera captures a license plate image for each truck bypassing the sensors. Using OCR software, the system attaches data to the image that indicates whether or not the plate was successfully read and the time, date and location of the read; and it also indicates whether or not the license plate number is in either a State or Federal crime database.

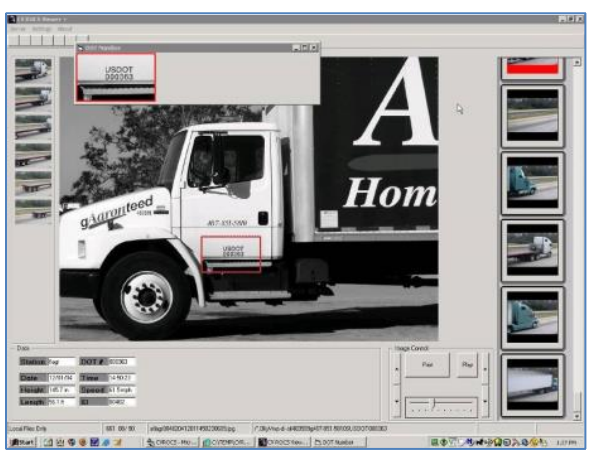


Source: Florida Department of Transportation

While LPR can be used to capture vehicle identification and conduct license plate "look ups," it cannot capture the weight of the vehicle. LPR technology is generally used in conjunction with WIM technology. While LPR is used in various applications around the world including toll enforcement, parking operations, and speed enforcement, it is still rather limited in its accuracy for trucking enforcement operations. Due to the large number of license plate designs, finishes (reflective), colors, and various states of disrepair (paint chipped off, dirty, bent, swinging from a hinge, odd location on the front of the truck, etc.) the technology has a limited "read" capability. However, vendors for such equipment continue to improve LPR technology performance.

Approximate Cost:

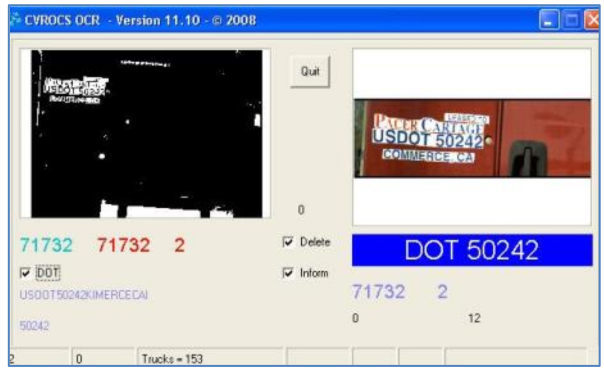
Costs for LPR systems will vary; installed costs range from $90,000 to $150,000 including OCR (Hanson, 2014). This includes the necessary software required to analyze the images and produce the digital numbers and text suitable for recordkeeping and running database queries. Annual maintenance costs can range from $8,100 to $13,500.



Source: Dr. Amr Oloufa

Optical Character Recognition (USDOT Readers)

Similar to LPR technology, optical character recognition technology in its simplest form is the application of a side-fired digital camera and sophisticated OCR software that takes the image of a USDOT number and converts that image to alpha-numeric characters. This USDOT information can be stored in a database or the software can “look up” the matching DOT number in a database that may contain DOT numbers of motor carriers with poor safety records, motor carriers that are delinquent on payment of International Registration Plan (IRP) or International Fuel Tax Agreement (IFTA) fees, or other violation information. This technology can be used in daylight as well as nighttime. The system employs various lighting techniques to illuminate the USDOT number, including infrared lighting, Xenon lighting, LED lighting, etc.



Source: Dr. Amr Oloufa

OCR systems can be used to identify motor carriers that consistently bypass weigh stations or that consistently operate when weigh stations are closed. Using this type of motor carrier-specific operations data—in conjunction with WIM scale data—enforcement officials can identify violators and respond with appropriate legal actions.

OCR, while becoming more popular, is still not close to 100 percent accuracy, and errors are not uncommon. Experience has shown that OCR performance has not matched that of LPR because of the technical challenges of interpreting the non-standard presentation of the USDOT numbers (varying size, color, location and background color).

Approximate Cost:

Costs for USDOT reader systems will vary; installed costs range from $90,000 to $150,000 including OCR. This includes the necessary software required to analyze the images and produce the digital numbers and text suitable for recordkeeping and running database queries. Annual maintenance costs can range from $8,100 to $13,500.

Source: Richard Easley

Container Character Recognition

Similar to LPR technology, container character recognition (CCR) technology is the application of a camera and sophisticated OCR software that takes the image of a container number and converts that image to text and numbers. This container ID information can be stored in a database or the software can search for a matching container number in a database that may contain stolen container information, Homeland Security information, or other information.

This technology can be used in daylight as well as nighttime. The system employs various lighting techniques, including infrared lighting, Xenon lighting, LED lighting, etc. Especially relevant for overweight violation detection and citation is the ability to identify the container separate from the chassis. Each chassis has a license plate, but if the container is transferred to a different chassis, the overloaded container could not be traced without the container's unique ID. Because chassis are an interchangeable component of all intermodal freight movements, a technology that specifically identifies the container, regardless of the chassis underneath, becomes valuable for locating overweight containers.

CCR systems can be used in the vicinity of marine and rail intermodal operations. This technology allows enforcement officials to track containers from the time they are unloaded from a ship or train until the container crosses jurisdictional boundaries. This information could be helpful in achieving the U.S. Department of Homeland Security's desire for cargo visibility, which could prove useful to State and local agencies as well as the Federal government.

CCR camera placement is not the same as LPR placement in that CCR cameras must capture the container number on the rear or side of the container whereas LPR must find and read the license plate on the front of the truck.

Source: Richard Easley

Approximate Cost:

Costs for these systems vary; the installed price is estimated between $90,000 and $150,000 including OCR. This includes the necessary software required to analyze the images and produce the digital numbers and text suitable for recordkeeping and running database queries. Annual maintenance costs can range from $8,100 to $13,500.

Transponder Technology (DSRC)

Transponder Technology is synonymous with Radio Frequency Identification (RFID) Tags or dedicated short range communications (DSRC) and uses radio frequency to communicate between a truck-mounted tag and a roadside tag reader. This two way communication link is primarily utilized on the Interstate system to identify a specific truck (or company) or run a quick database check to determine if the truck is in compliance (paid taxes, etc.). It can also alert the driver to pull into the weigh station or port-of-entry to be inspected. Transponder readers need to be compatible with transponders used for any particular DSRC system.


Source: North Carolina Highway Patrol

One of the advantages of using RFID technology is that it can identify the motor carrier as the truck travels down the highway without decreasing speed. As long as the jurisdiction has a database link to the truck, a great deal of information can be obtained – especially when married with a WIM system. When combined with a WIM system, commercial vehicle enforcement officers can stop the truck and issue an overweight citation (using a portable or static scale) or the data can be analyzed at a later date and warnings can be issued to the offending motor carriers. The disadvantage of DSRC in this application is that it can only identify the carrier and the truck; without combining DSRC with WIM, there is no weight information. The other challenge with relying solely on using DSRC for vehicle identification is that only a very small percentage of trucks actually carry these DSRC tags and participate in the electronic screening programs. To compound this, the various DSRC programs are not interoperable, so a transponder that can be identified in one State may not be recognized in another State.

Approximate Cost:

The costs for DSRC screening technology is approximately $25-$75 per tag. Depending upon the program the carrier enrolls with, the carrier may or may not have to purchase the tag. Additional costs are necessary to purchase transponder readers, deploy the requisite communications technology, and install/support the software programming necessary to operate the system.

<u>CVIEW and Automated Permitting Systems</u>

The Commercial Vehicle Information Exchange Window (CVIEW) is a system that allows enforcement personnel to collect the pertinent data for a commercial vehicle from several disparate databases. Rather than stopping a commercial vehicle and then checking multiple databases for information pertaining to operating authority, possession of appropriate permits, etc., the CVIEW software system searches all relevant databases and compiles the information on one screen so the enforcement officer can run all necessary checks and the commercial vehicle driver is not delayed any longer than necessary.

Source: Florida Department of Transportation

Automated Permitting Systems allow the motor carrier to apply for, pay for, and receive oversize and overweight permits online in an automated fashion. This method is much quicker for the motor carrier and allows permit office personnel to concentrate on more complex duties while the simple permit requests are handled through an automated process. An automated permitting benefits both the motor carrier and permit office staff in terms of efficiency, but it also benefits enforcement personnel at the roadside because the overweight or oversized vehicles' permits can quickly be verified through a CVIEW link to the automated permit database.

Approximate Cost:

CVIEW technology costs vary from jurisdiction to jurisdiction and depend upon the legacy system interfaces as well as development of any new databases. A CVIEW (or CVIEW equivalent) can cost as little as $30,000 or as much as $600,000. Annual maintenance costs for these systems can range between $2,700 and $54,000 depending upon the complexity of the system.

Automated Permitting Systems can vary greatly in price as well. An important factor is the required system functionality. The complexity of the programming greatly increases the cost. Also, some jurisdictions have the ability to develop their own systems while other jurisdictions choose to hire an outside vendor to create their program. Still other systems are created and operated by a third party vendor that charges service fees to the jurisdiction, thereby reducing the initial programming and hardware procurement cost.

Technology Systems

Technologies serve a specific purpose and most are designed to fulfill that purpose efficiently and effectively. It is often advantageous to deploy combinations of technologies to satisfy multiple and varying enforcement objectives. Such strategic enforcement systems utilize the technologies discussed previously.

The following technology system descriptions will vary from agency to agency depending upon capital budgets, locations, traffic conditions, weather, availability of space, type of freight movements, and availability of weight enforcement personnel.

Non-Fixed Weigh Sites

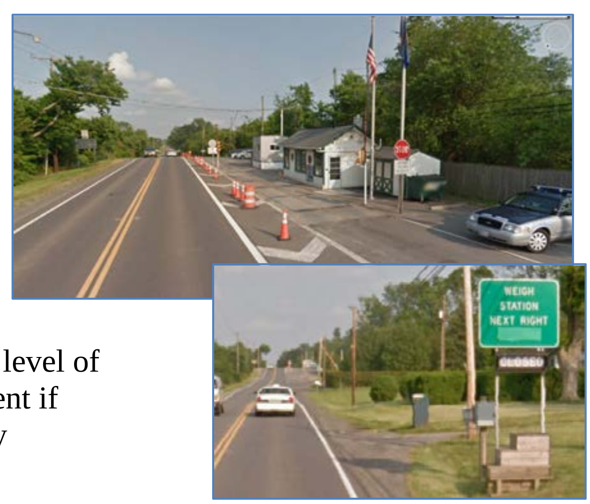
Non-fixed weigh sites are those locations that are used for inspections or weighing vehicles. Unlike weigh stations which are typically staffed and fully configured for commercial vehicle enforcement activities, non-fixed weigh sites are locations that are not staffed, may or may not have any commercial vehicle enforcement equipment, and are only utilized on a temporary basis. For purposes of this report, only the following two types of non-fixed weigh sites will be discussed.

- Plug and Play Sites
- Roving Sites

Both Plug and Play Sites, and the Roving Sites have a variety of configurations. They are used for conducting short term enforcement activities with a relatively low budget. However, once the commercial vehicle industry members that are operating illegally learn where a non-fixed weigh site is in operation, they may either reroute their trips or park and wait for the non-fixed weigh site to shut down – typically, just a matter of hours.

Plug and Play Sites

Plug and Play sites are those locations where some level of infrastructure exists but it is not used for enforcement if enforcement officers are not onsite. There are many



Source: Google Earth

configurations for this type of site, and any number of combinations of infrastructure may accommodate the types of technology used in such sites, including:

- Weigh-in-Motion Technology
- License Plate Reader Technology
- Closed Circuit Television Cameras
- Optical Character Recognition (for USDOT number reads)
- Container Character Recognition (for container number reads)
- Variable Message Signs (to alert trucks to stop)
- Height Detection Technology
- A small building structure to house or plug in computer equipment to operate any of the onsite technology

Plug and Play sites can also have any combination of equipment brought along with the enforcement personnel to complement the existing equipment already onsite. This can include:

- Portable Scales
- Thermal Imaging Technology

Approximate Cost:

The cost for a Plug and Play site is dependent upon the technologies used at the particular location. Some Plug and Play sites may be configured differently depending upon geographic limitations or the targeted violator group (e.g., logging trucks, containers, etc.).

<u>Roving Sites</u>

Roving Sites are those locations chosen for commercial vehicle enforcement activities that contain no enforcement facilities or technologies but simply have enough space to perform weighings and inspections safely. These sites are typically chosen based on a calculated enforcement strategy.

Source: Richard Easley

A roving site could be located at:

- A rest area parking lot,
- A paved or gravel pullout along the roadway, or
- Any site deemed safe for weighing and inspection that is utilized by commercial vehicle traffic.

Roving sites require the commercial vehicle enforcement personnel to bring all of the equipment they would need to conduct their weighings and inspections. The combination of equipment used at a Roving Site depends upon the objectives of the inspections. A roving site could be a random location to pull over one truck based on a suspected safety violation, or it could be a pre-determined location where all trucks are stopped along that particular route. Inspections could be for any combination of the following objectives:

- Checking weight of the vehicles,
- Conducting an equipment check (brakes, cargo securement, tires, lights, etc.),
- Driver credentials or operating credentials (IRP, IFTA, permits, etc.), or
- Other reasons.

Equipment utilized at a Roving Site could include:

- Portable Scales
- Semi-Portable Scales (larger scales that require a hauling trailer and assembly is required)
- Portable Transponder Reader
- Thermal Imaging Device
- Brake Testing Device

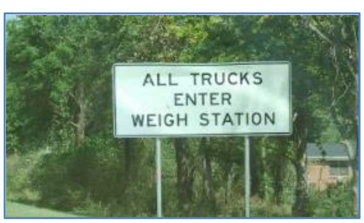
Some enforcement agencies use vans that are adequately equipped to set up inspection or weigh sites at any location deemed appropriate.

Approximate Cost:

The cost for a Roving Site is dependent upon what technologies would be used at the particular location. Some Roving Sites may require different equipment depending upon the geographic limitations, objective of the mission, etc.

Fixed Weigh Sites

Fixed weigh sites are those locations that are permanent and have staff assigned to operate them. Commercial vehicle enforcement personnel operate the facility on a regularly scheduled basis.



Source: Richard Easley

Some sites operate 24 hours per day while others may shut down every evening. Fixed weigh sites typically require a large amount of land and can be very expensive to build. Space requirements vary by jurisdiction. Some jurisdictions require office space for multiple agencies (e.g., weight enforcement and law enforcement). In some areas of the country all weigh station activities are conducted under a single agency while in others States share duties between various agencies. Fixed sites are usually located on high-volume roadways (Interstate System, National Highway System routes, etc.) and several activities are conducted onsite. These activities can include:

- Weighing the trucks (issuing citations if warranted),

- Conducting safety inspections,
- Issuing permits,
- Checking for proper operating credentials,
- Examining Bills of Lading to ensure taxes are paid and cargo is not prohibited,
- Providing restroom facilities for drivers, and
- Providing a parking area for trucks that are placed out of service or for drivers that need rest (some include WiFi).

The fixed weigh sites can use many technologies to perform commercial vehicle enforcement duties more efficiently. The technologies that can be found at a fixed weigh site can include:

- Static Scales
- Weigh-in-Motion
- License Plate Readers
- Optical Character Readers (USDOT Readers)
- Container Character Reader
- CCTV
- Thermal Imaging
- Height Detectors
- Three Dimensional Imaging
- Brake Testing Technologies
- Vehicle and Cargo Inspection Systems (VACIS)
- Transponder Readers

Source: Florida Department of Transportation

Fixed weigh sites are costly and most jurisdictions have found that while the need for more sites is increasing, the costs for additional sites makes building the number of facilities needed cost prohibitive. Because there are relatively few fixed weigh sites and many route alternatives, some motor carriers that may be overweight or unable to pass a safety inspection find bypass routes to avoid being stopped at a fixed weigh site. Also, some carriers find that they lose valuable time when they have to undergo inspections or other time consuming requirements at fixed weigh sites and attempt to find bypass routes. The technologies operating at fixed weigh sites help to minimize commercial vehicle delays by automating time consuming activities, but these technological advancements have minimal value if overweight and unsafe carriers choose to find bypass routes and never enter a fixed weigh site.

Approximate Cost:

Source: Richard Easley

Fixed weigh sites can cost upwards of $15 to $35 million dollars depending upon the weigh site configuration, the various environmental studies, construction costs, land acquisition costs, etc. The VACIS technology by itself can cost more than $1.5 million dollars. The VACIS utilizes gamma ray technology to produce images revealing cargo content without the need to open trailers or containers. Annual maintenance costs for technologies associated with a fixed weigh site can average $80,000, depending upon the configuration (Taylor, 2014).

<u>Unmanned Fixed Weigh Sites</u>

The unmanned fixed weigh site is similar in concept to the fixed weigh site, but it is operated remotely. This concept is one that allows enforcement personnel to use technology to weigh vehicles, check vehicle dimensions, determine if a vehicle is current on taxes, registrations, permits, etc. This concept also allows for thermal imaging brake checks as well as visual inspections. While unmanned fixed weigh sites cannot match the full services that a fixed weigh site can with onsite enforcement personnel, it utilizes technology to the fullest extent to perform some basic weigh site functions.

One of the models of an unmanned fixed weigh site is to use channelized lane flows that direct trucks to a window-height kiosk with a camera. The driver is then asked questions, if warranted, and required to places any needed paperwork on the scanner located in the kiosk. This information is relayed to the weigh station operator that may be at the manned fixed weigh station on the opposite side of the highway, or the operator may be in a central location where multiple unmanned fixed weigh sites across the jurisdiction are managed.

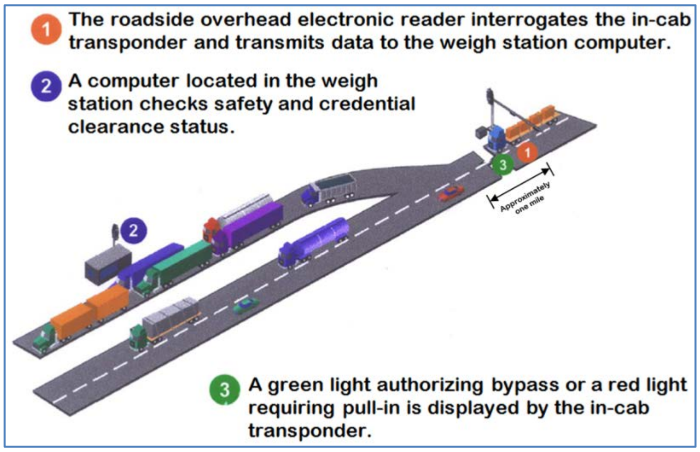
The configurations for an unmanned fixed weigh site can vary greatly, but typically will have CCTV visibility, static scales, WIM technology, and perhaps restroom facilities. Most will have ample parking space for vehicles to wait until enforcement personnel arrive to provide assistance or issue citations if warranted. This space can also be used when vehicles are placed out of service for oversize or overweight violations, incomplete paperwork, or visual safety inspection irregularities.

Approximate Cost:

Costs for unmanned weigh sites vary depending upon the size and cost of real estate and needed improvements (pavement, utilities, construction, etc.), the technologies deployed, and the facilities included (restrooms, small office, etc.). Costs range from $10 – $20 million. Annual maintenance costs for technologies associated with an unmanned fixed weigh site can average $80,000, depending upon the configuration (Taylor, 2014).

Electronic Screening Systems

Electronic screening systems originated in the early 1990's to demonstrate the concept that trucks could travel from Texas to California and north to British Columbia without being required to stop at weigh stations. This electronic screening demonstration would enable those carriers that are operating safely and legally to bypass crowded weigh stations so long as they continue to operate safely and legally. The concept for electronic screening systems is based on an electronic check of a truck or motor carrier's information, which is located in a database and accessed when the truck comes into the vicinity of a weigh station. If, based on the information in the jurisdiction's database, the truck is deemed to have a satisfactory safety record and is operating with all legally required credentials, the driver is electronically notified that he/she may bypass the weigh station.



Source: PrePass

Electronic screening programs exist in most States today, but not all systems are interoperable. There are variations in communication methods, variations in technology system requirements, variations in database ownership (State-owned or third-party-provider owned database for checking motor carrier records to determine eligibility for weigh station bypass), and variations in cost structures for electronic screening systems (State funded, motor carrier funded, or combination).

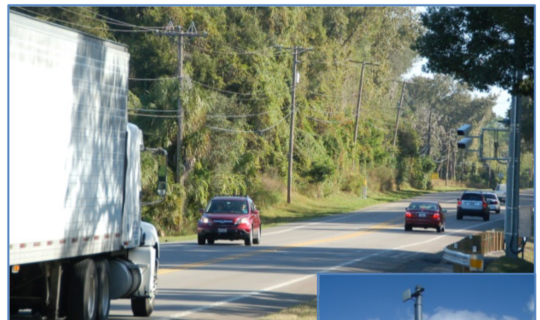
Electronic screening systems use a combination of technologies including:

- Transponders and Transponder Readers
- Weigh-in-Motion
- Cellular Communications (smart phones, e-tablets, laptops, etc.)

Industry representatives have expressed a desire to have a single communication protocol that works for every jurisdiction and is interoperable for all vehicle-to-roadside communication links. The 5.9 GHz communications spectrum has specifically been researched to become the standard transportation link that can support electronic screening nationwide as well as allow enforcement-vehicle-to-commercial-vehicle system interrogations (for safety and weights) while both vehicles are in motion, minimizing the need to stop commercial vehicles. A nationwide interoperable communication system may

Source: North Carolina Highway Patrol

provide the basis of the North American Vehicle to Infrastructure (V2I) and the Vehicle to Vehicle (V2V) wireless communication network developed for rapid transmission of critical, life-saving information.



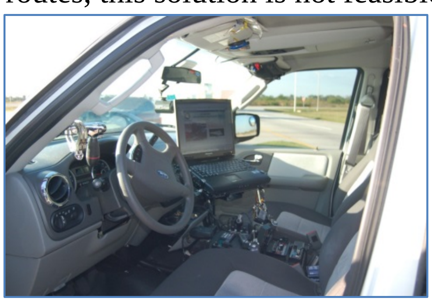
Source: Richard Easley

Approximate Cost:

Costs for electronic screening systems vary greatly and can be borne by any or all of the following stakeholders – the jurisdiction, a third party provider, and the motor carrier community. Cost items could include transponders, transponder readers, smart phones, e-tablets, cell phone service, weigh-in-motion, hardware/software systems, construction costs, plus software and system integration costs. A typical electronic screening site equipped with one to three transponder readers and the associated technology (not including the transponders) can cost between $200,000 and $600,000 ($200,000 for one transponder reader configuration and $600,000 for a three reader configuration) (Taylor, 2014). These costs do not include the addition of WIM technology. Annual maintenance costs can range between $18,000 and $54,000.

Virtual Weigh Sites

Virtual weigh sites are a cost-effective substitute for placing permanent weigh stations on every road in a particular jurisdiction. There is a high probability that if a truck is deliberately running overweight, the driver may choose to take routes that avoid weigh stations. Due to the existence of primary and secondary roads, there is usually at least one alternate route around every fixed weigh station. While it might seem logical to build weigh stations on several of the alternate routes, this solution is not feasible. The cost for such facilities, including purchasing the right of way and construction, can easily exceed $15 million. By comparison, the average virtual weigh sites can cost as little as $300,000 depending upon the configuration. A significant difference between the virtual weigh site and the fixed or unmanned weigh site is that the virtual weigh site has a nearly invisible footprint. That is to say that there is no exit ramp, there is no building, there is very little evidence that a virtual weigh site exists unless someone notices a loop detector in the roadway or a license plate camera mounted on a pole on the side of the roadway. Virtual weigh sites do not require commercial vehicles to stop, slow down, change lanes or any other behavior inconsistent with "regular driving."



Source: Richard Easley

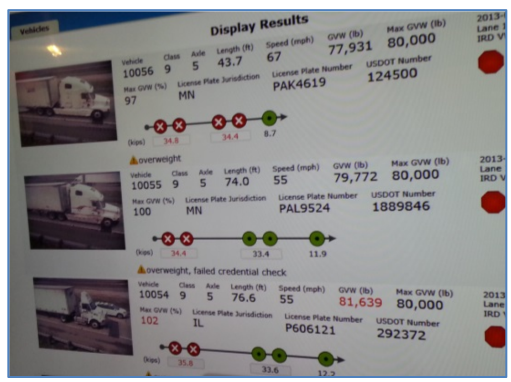
The typical virtual weigh site system is designed to detect possible overweight vehicles on roadways that bypass a fixed weigh site. The system is designed to screen all commercial vehicles using the roadway and to categorize them as either potential violators or non-violators. Law enforcement personnel can then focus their attention on potential violators. Potential violators will be any vehicles that appear to either violate the jurisdiction's weight or dimension requirements or avoid the WIM scale purposefully.

Virtual weigh systems are automated. WIM technology determines vehicle weights. Each truck traversing the outfitted roadway will trigger cameras to take an image of the truck's license plate. Optical character recognition (OCR) software will convert the license plate image into numbers which can be stored as data. Additionally, if the WIM sensor indicates the truck is overweight, an appropriately configured virtual weigh site can trigger a side view camera to capture a digital image of the overweight vehicle. The system will then marry these three pieces of data and send an image, via wireless communication, to the motor carrier enforcement computer located in a central office where it can be stored and can be accessed (via secure internet access) by an enforcement officer's laptop computer (or smartphone) at a roadside location. The image may consist of the digital photo of the vehicle superimposed with WIM data and the license plate number. Those trucks that are overweight can also trigger an alert to the weigh station personnel at the closest facility.

It is important to note that it is not a crime to avoid a weigh station by circumventing it with an alternate route; however, this system captures data on non-violators and allows enforcement personnel to identify the trends of various carriers. This can lead to targeted inquiries as to why a motor carrier consistently bypasses the weigh station.

Virtual weigh systems can have many configurations and also employ various types of technologies depending upon the needs and budget of the jurisdiction's commercial vehicle enforcement program. Technologies can include:

- Weigh-in-Motion
- License Plate Readers
- Transponder Readers
- Optical Character Recognition (USDOT Number Reader)
- Container Character Recognition
- CCTV
- Height Detection System
- Three Dimensional Imaging
- Thermal Imaging



Source: International Road Dynamics, Inc

The data collected by these systems can provide speeds, weights, time of day, vehicle identification, motor carrier identification, vehicle height, vehicle length, indication of brake malfunction, status of motor carrier operating credentials, determination of stolen vehicle (license plates), and support Amber Alerts, Silver Alerts, or criminal BOLO (be on the lookout) alerts.

Approximate Cost:

The costs to deploy virtual weigh sites are entirely dependent upon each system's purpose, technological configuration, and available communications network. Some of the more basic systems can cost less than $100,000 (with basic WIM and an onsite data collection device) or can approach $700,000 for a sophisticated, fully equipped site (Taylor, 2014). Annual maintenance costs range between $9,000 and $63,000.

Alternative Technology Approaches

There are several technology-related alternatives in existence to support commercial vehicle size and weight compliance and enforcement. Some of these technologies are used solely for data collection, some for preserving infrastructure elements, and others for helping the motor carrier community achieve compliance without enforcement intervention.

Bridge Weigh-in-Motion

A 2007 FHWA scanning report (USDOT, FHWA, 2007, p.5) discusses what can best be described as "Bridge WIM." According to the report, Slovenia has emerged as a leader in the development of this bridge WIM system technology.

Source: FHWA

With this system, weight detection equipment is applied to the bottom of a bridge slab. This location eliminates the need to disrupt traffic on the bridge during installation. Multiple sensors are installed, and it is reported that axle weights, gross vehicle weights, axle spacing, vehicle speeds, and vehicle classification can be captured if the technology is correctly installed. The vehicle weights are reportedly accurate enough to use for enforcement screening. The Slovenia Bridge WIM system typically uses 16 sensors to measure the weights over two lanes of traffic. These sensors are a series of strain transducers mounted under the bridge deck that "measure" the weight of vehicles passing over the bridge. The system can also be configured with a camera to capture video images of the vehicles being weighed. These images, along with the weights of the trucks, can be electronically stored or transmitted to a downstream enforcement site.

Source: Connecticut DOT/USDOT FHWA

A similar Bridge WIM project was undertaken by Connecticut DOT (ConnDOT). This system also used sensors to measure bridge strain from a steel girder bridge. ConnDOT and the University of Connecticut determined that Bridge WIM, as tested, provided gross vehicle weight accuracy levels that were ±16 percent. While this level of accuracy is not sufficient for enforcement purposes, it is a good sorting mechanism (loaded vs. empty trucks) and could be useful for planning applications. A study of the Connecticut project recommends further research to improve and refine this concept (Wall et al., 2009, p 41).

<u>Roadway-Driver Interface</u>

The Florida Department of Transportation, with support from the Florida Atlantic University and the University of Central Florida, conducted a pilot test at the Port of Jacksonville. This initiative proved the feasibility of utilizing WIM, Three Dimensional Imaging, CCTV, License Plate Reading Technology, Container Character Recognition, Optical Character Recognition (USDOT reader), and a mini weather station combined with a dynamic message sign to inform commercial vehicle drivers of their truck weights and give them the opportunity to operate legally if an overweight permit is required.

The system was set up at a Port of Jacksonville container terminal exit (in the right lane of two lanes) and each truck had the opportunity to drive over the WIM and see their weights posted in real-time on the dynamic message sign strategically located where they could see it. This information allowed those motor carriers operating overweight to contact their dispatcher to obtain a permit so they could operate legally.

The system recorded multiple instances where drivers deliberately moved into the lane with the WIM to view the weight of their vehicle upon exiting the terminal, illustrating the drivers' desire to know the operating weight of their vehicles.

Source: Dr. Amr Oloufa

On-Board Weighing

Source: John Seton

Another approach that is in use today, but could be expanded in the near future, is the use of On-board scales. While primarily used by industry in the United States as a self-check enhancement, Australia routinely requires operational on-board weighing systems as an approval condition for an overweight load to receive a permit under Australia's Intelligent Access Program. Compliance with permitted vehicle weight limits is monitored by enforcement through a commercial mobile radio connection to the vehicle while it is in transit. This technology uses equipment on board the truck and trailer to determine the weight of the vehicle as it is loaded. This data can be used by the commercial motor vehicle industry for invoicing purposes when picking up and delivering loads. With the emerging Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) systems that are in early stages of deployment, the on-board scales can be utilized by properly equipped enforcement vehicles to determine the weights of trucks while in motion and potentially eliminate any need to stop at weigh sites.

Alternative Programmatic Approaches

In addition to the alternative enforcement technologies mentioned above, there are also alternative programmatic approaches to weight enforcement. These may or may not involve the use of one or more technology components previously mentioned. There are a variety of complex considerations and challenges for each of these enforcement approaches; for a detailed summary of these, plus detailed information on specific international and US. State-specific programs, see **Appendix A**. The following are short descriptions of three alternative approaches which were documented during the literature review conducted as part of the 2014 CTSW Study. During the literature review the majority of the "alternative approaches" could be categorized into the following three types of programmatic enforcement approaches: chain of responsibility, accreditation schemes or incentive programs, and relevant evidence.

In a chain of responsibility enforcement program, all entities in the supply chain—consigning, loading, carrying, driving, and receiving—are held responsible for assuring that the commercial vehicle which is transporting the load operates legally (Leyden et al., 2004, p. 6). If weight enforcement laws are broken, under this type of program, penalties can be applied to any or all of the entities in the supply chain. In Australia, their chain of responsibility program also aims to integrate responsive regulation, which provides a range of penalties tied to each company's relative risk in assuring compliance and past performance (Jones, 2012, pp. 9-10).

Accreditation schemes and incentive programs can be voluntary or mandated. In these types of programs, operators certify their compliance through an audit process. In some instances, operators that achieve regulatory compliance are rewarded with productivity incentives, such as allowance to operate above the basic truck size and weight limits or less frequent site visits for company audits and vehicle inspections (OECD 2011, pp. 284-287).

Civil weight enforcement or "relevant evidence" programs (such as in Minnesota) allow enforcement officers to review bills of lading or other forms of truck weight records at a shipper or motor carrier office to be used as legal evidence that an overweight violation has occurred (Thooft, 2013). Other relevant evidence that may be used in this type of program is WIM data that identifies habitual offenders. This information can be used by enforcement personnel to target these companies for site visits or civil citations. (URS, 2005, p. 51). New York State also uses an administrative law process to review inspection reports and traffic information "after the fact" to place additional fines on egregious violators (McDonough, 2013).

<u>Summary and Potential Technology Implications</u>

Table 4 provides a summary of this description of enforcement technologies, focusing on the costs for equipment, installation, and annual maintenance for these technologies.

A concern associated with allowing heavier and longer trucks into the traffic stream is the potential for these vehicles to escalate enforcement costs because the enforcement task becomes more onerous or the trucks exceed the capacity of existing enforcement technologies. Based on the review of enforcement technologies provided in this sub-section, this potential concern appears valid only for fixed static scales, portable scales, and semi-portable scales, as the operation and performance of the other technologies and systems will continue to be just as effective.

Truck configurations with more axles or axle groups will require additional weighing time if weighed using static scales designed to weigh axle groups, semi-portable scales, or portable scales. Longer trucks may exceed the length capacity of fixed static scales designed to weigh the entire truck at once. The costs for replacement of new and longer scales would not be insignificant.

Table 4: Summary of Current TSW Enforcement Technology Costs

Technology or System	Cost Range (Equipment & Install) [current US Dollars]	Maintenance Cost Range (Annual) [current US Dollars]
TSW Enforcement Technologies		
Fixed Static Scale	\$100,000 – \$200,000	\$9,000 – \$18,000
Portable Scale	\$2,000 – \$4,700	\$180 – \$425
Semi-portable Scale	\$10,000 – \$59,000	\$900 – \$5,300
WIM Piezoelectric	\$25,000 – \$30,000	\$2,250 – \$2,700
WIM Piezoquartz (Kistler)	\$45,000 – \$60,000	\$4,100 – \$5,400
WIM Bending Plate	\$55,000 – \$65,000	\$5,000 – \$5,900
WIM Load Cell	\$100,000 – \$150,000	\$12,600 – \$16,200
Thermal Imaging		
- Hand held	\$6,000 – \$10,000	\$540 – \$900
- Mobile van	\$300,000	\$27,000
- Fixed site	\$150,000 to \$250,000	\$13,500 – \$22,500

Technology or System	Cost Range (Equipment & Install) [current US Dollars]	Maintenance Cost Range (Annual) [current US Dollars]
TSW Enforcement Technologies		
Height Detection	$30,000	$2,700
3-D Measuring	$235,000	$21,200
Closed Circuit TV	$10,000 – $50,000	$200 – $1,000
License Plate Recognition	$90,000 – $150,000	$8,100 – $13,500
Optical Character Recognition	$90,000 – $150,000	$8,100 – $13,500
Container Character Recognition	$90,000 – $150,000	$8,100 – $13,500
TSW Enforcement Technology Systems		
Fixed Weigh Site	$15M – $35M	$80,000
Unmanned Weigh Site	$10M – $20M	$80,000
Electronic Screening System	$200,000 – $600,000	$18,000 – $54,000
Virtual Weigh Site	$100,000 – $700,000	$9,000 – $63,000

According to the National Institute of Standards and Technology (NIST) Handbook 44 (NIST 2011, p. 2-50), any weighings of traded commodities must be weighed by single draft method (see excerpt below).

> **UR.3.3. Single-Draft Vehicle Weighing. –** A vehicle or a coupled-vehicle combination shall be commercially weighed on a vehicle scale only as a single draft. That is, the total weight of such a vehicle or combination shall not be determined by adding together the results obtained by separately and not simultaneously weighing each end of such vehicle or individual elements of such coupled combination.
>
> However, the weight of a:
>
> (a) Coupled combination may be determined by uncoupling the various elements (tractor, semitrailer, trailer), weighing each unit separately as a single draft, and adding together the results; or
>
> (b) Vehicle or coupled-vehicle combination may be determined by adding together the weights obtained while all individual elements are resting simultaneously on more than one scale platform.
>
> **Note:** This paragraph does not apply to highway-law-enforcement scales and scales used for the collection of statistical data. (Added 1992)

The Note in the excerpt above states that the NIST requirement does not apply to highway law enforcement. With respect to the static scales currently in use for law enforcement, many States have developed procedures, polices, and statutes that permit truck weighings on static scales that are smaller than the actual length of the tractor and trailer. If there allowable truck lengths on the Nation’s highways were to increase, the same State-developed procedures, policies and statutes in use today could be utilized with no additional equipment replacements or costs.

National-Level Trends

This sub-section describes enforcement program costs and resources at the national level, including an analysis of the available enforcement program funding reported annually in each State’s State Enforcement Plan (SEP) as enforcement program costs. In addition, the SEPs indicate the quantity and type of weigh scales used for truck weight enforcement on an annual basis. The analyses identifies characteristics and trends in program costs and weigh scale usage for 2008 through 2012 for all reporting States.

Enforcement Program Costs

Nationwide, the total cost of delivering truck size and weight enforcement programs as reported in the SEPs increased between 2008 and 2012 from approximately $489 million in 2008 to $613 million in 2012 (in 2011 US Dollars (USD)). **Table 5** shows the total cost (in 2011 USD) for each of these years and the number of States for which cost data were available in each year. The table also reports program costs as they are reported in each of the 5 years without adjusting for inflation; these costs are shown in italics. The increase in total costs—particularly between 2009 and 2010—is partly due to the increase in the number of reporting States (from 41 to 48). The only evident year-to-year cost decrease (in 2011 USD) during this five-year period occurred between 2010 and 2011, when the same 48 States reported total costs in each year. The reported cost data are obtained from SEPs submitted by a total of 50 States, including the 49 jurisdictions in the contiguous United States and Alaska. For two States, cost data were unavailable in each of the 5 years.

As shown in **Table 5**, the total TSW enforcement costs do not account for enforcement activity in all States. Adjusting for the two States where cost data were unavailable, the total nationwide 2011 TSW enforcement cost could be approximately $635 million. Thus, when estimating total costs for all States, the total is about 6 percent higher than the sum of the reported 2011 costs (in 2011 USD). This estimate is calculated by first normalizing each State's total enforcement cost by dividing it by the total truck VMT in that State. Then, using the median value of cost per truck VMT for the reporting States, the total costs in the two non-reporting States are estimated by applying this median value to the truck VMT in those States.

Table 5: Nationwide Truck Size and Weight Enforcement Program Costs for All Reporting States: 2008-2012

	Enforcement Program Costs (in millions of 2011 USD)[1] *Enforcement Program Costs (in millions of reported year USD)*				
	2008	**2009**	**2010**	**2011**	**2012**
Total	$ 489 *$ 468*	$ 546 *$ 520*	$ 612 *$ 593*	$ 600 *$ 600*	$ 613 *$ 626*
# of States	41	41	48	48	47

[1]All costs are normalized to 2011 USD using the Consumer Price Index published in December 2013 by the Bureau of Labor Statistics.

The inconsistencies in the cost data submitted by States over the 5-year period inhibit a reliable analysis of annual trends in TSW enforcement program costs. Therefore, the trend analyses include only the 32 States that provided data about total enforcement program costs and the allocation of costs to facilities and personnel in each of the 5 years (2008 to 2012, inclusive). As shown in **Table 6**, for these 32 States, total enforcement program costs (in 2011 USD) increased from $432 million in 2008 to $489 million in 2010, then decreased to $475 million in 2011 before rising to $487 million in 2012. The table also reports program costs as they are reported in each of the 5 years without adjusting for inflation; these costs are shown in italics.

Table 6 also shows annual costs for personnel and facilities for the 32 reporting States. Personnel costs (in 2011 USD) exhibit a similar pattern as total costs, increasing from $348 million in 2008 to $419 million in 2010 before decreasing to approximately $411 million in 2011 and 2012. Proportionally, when aggregating costs for all 32 States, personnel costs represent approximately 85 percent of total costs in 2010, 2011, and 2012. The proportions of personnel costs to total costs in 2008 and 2009 are influenced by anomalies in the reported facilities and other costs for a single state.

Reported facilities costs (in 2011 USD) are highest in 2008 at nearly $80 million, then decrease to less than $65 million annually from 2009 to 2011 before increasing back to $74 million in 2012. The inclusion of both capital and operating expenditures as part of the facilities costs gives rise to year-to-year fluctuations in certain States. In particular, the relatively high facilities costs in 2008 results from an unusually high cost reported in a single State. The other costs shown in **Table 6** represent the difference between the total cost and the sum of the personnel and facilities costs. These costs are relatively small, except for in 2009 when the total costs reported in a single State were substantially higher than the sum of the personnel and facilities costs in that State. The reason for this discrepancy is not apparent in that State's SEP.

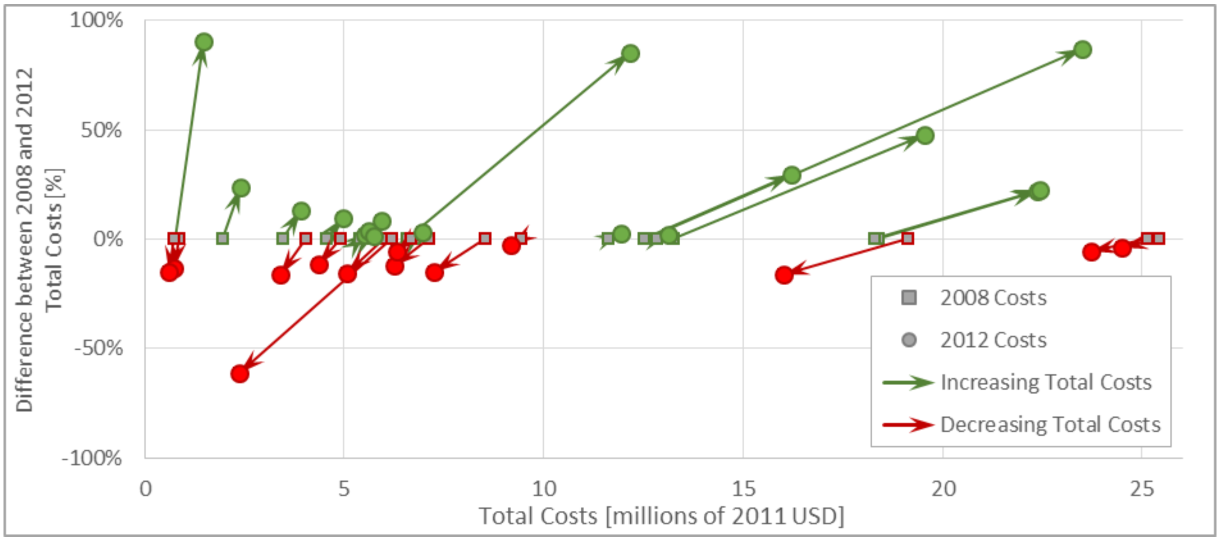
Table 6: Nationwide Truck Size and Weight Enforcement Program Costs for 32 Reporting States: 2008-2012

	Enforcement Program Costs (in millions of 2011 USD)[1] *Enforcement Program Costs (in millions of reported year USD)*				
	2008	**2009**	**2010**	**2011**	**2012**
Total	$ 432 *$ 414*	$ 480 *$ 458*	$ 489 *$ 474*	$ 475 *$ 475*	$ 487 *$ 497*
Personnel	$ 348 *$ 333*	$ 363 *$ 346*	$ 419 *$ 406*	$ 411 *$ 411*	$ 412 *$ 420*
Facilities	$ 80[2] *$ 76*	$ 62 *$ 59*	$ 65 *$ 63*	$ 61 *$ 61*	$ 74 *$ 75*
Other[3]	$ 4 *$ 4*	$ 55 *$ 53*	$ 5 *$ 5*	$ 4 *$ 4*	$ 2 *$ 2*

1 The costs shown in the table are summed for the 32 States that reported total (non-zero) costs for each year from 2008 to 2012, inclusive, in the total, personnel, and facilities cost categories. All costs are normalized to 2011 USD using the Consumer Price Index published in December 2013 by the Bureau of Labor Statistics.
2 The relatively high facilities costs in 2008 results from an unusually high cost reported in a single State.
3 Other costs represent the difference between total costs and the sum of personnel and facilities funding. These costs are relatively small, except for in 2009 when the total costs reported in a single State were substantially higher than the sum of the personnel and facilities costs in that State. The reason for this discrepancy is not apparent in the State's SEP.

The characteristics and trends evident in **Table 6** provide a national perspective on TSW enforcement program costs; however, this perspective masks the variation and trends in program costs for individual States. **Figure 1** depicts the difference between 2008 and 2012 reported total TSW enforcement costs by state. Of the 32 reporting States, 19 reported an increase in total costs and 13 reported a decrease. In terms of the magnitude of these changes, nine States reported a cost increase of over 20 percent, whereas one State reported a cost decrease of over 20 percent. Of these nine States, six experienced increases in both personnel and facilities costs while the remaining three experienced increases in personnel costs only. Cost reductions for both personnel and facilities contributed to the cost decrease in the State reporting a cost decrease of over 20 percent.

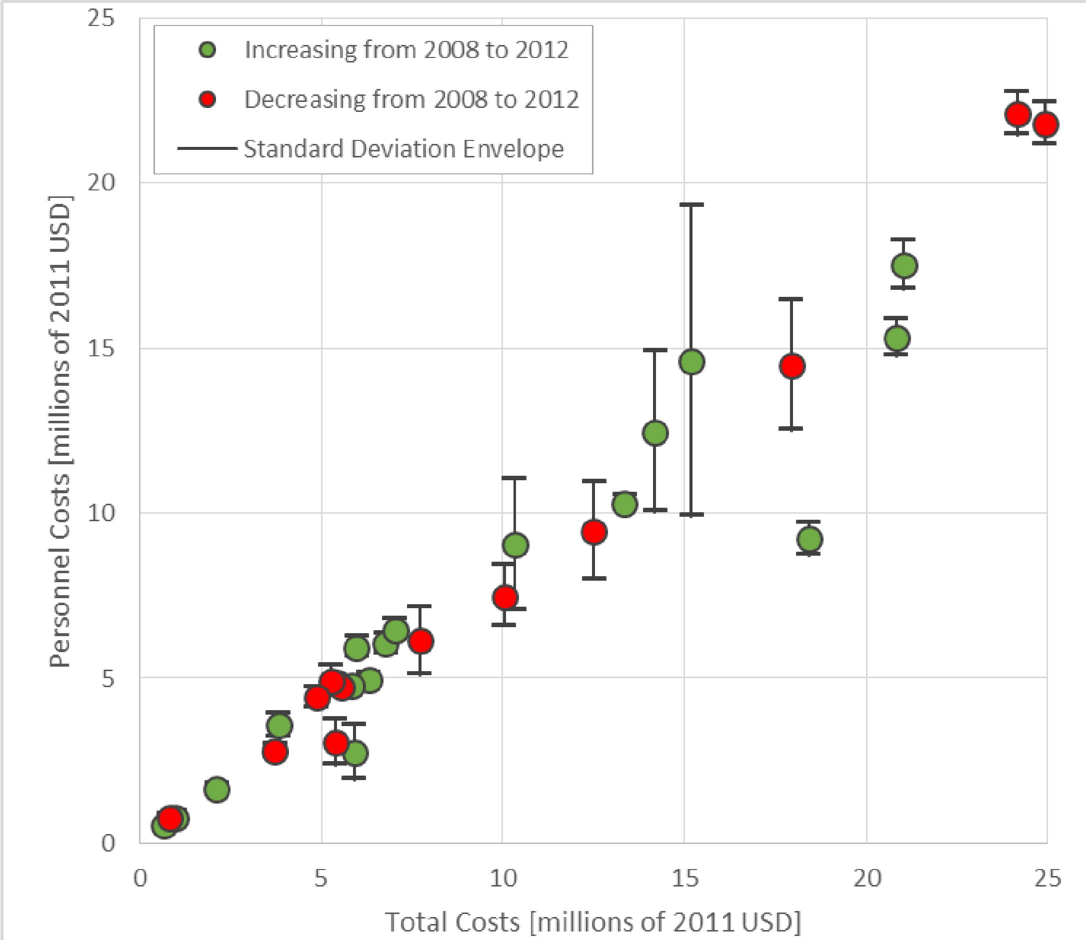
Figure 1: Difference Between 2008 and 2012 Total TSW Enforcement Costs by State



Notes: The costs plotted in the figure are for 2008 and 2012 only and do not reflect costs reported in 2009 through 2011, inclusive. The figure depicts 30 of the 32 reporting States; two States have not been plotted because their total costs exceed the scale of the figure. One State had a total cost of $107 million (2011 USD) in 2008 that increased 28 percent by 2012; the other State had a total cost of $55 million (2011 USD) in 2008 that increased 3 percent by 2012.

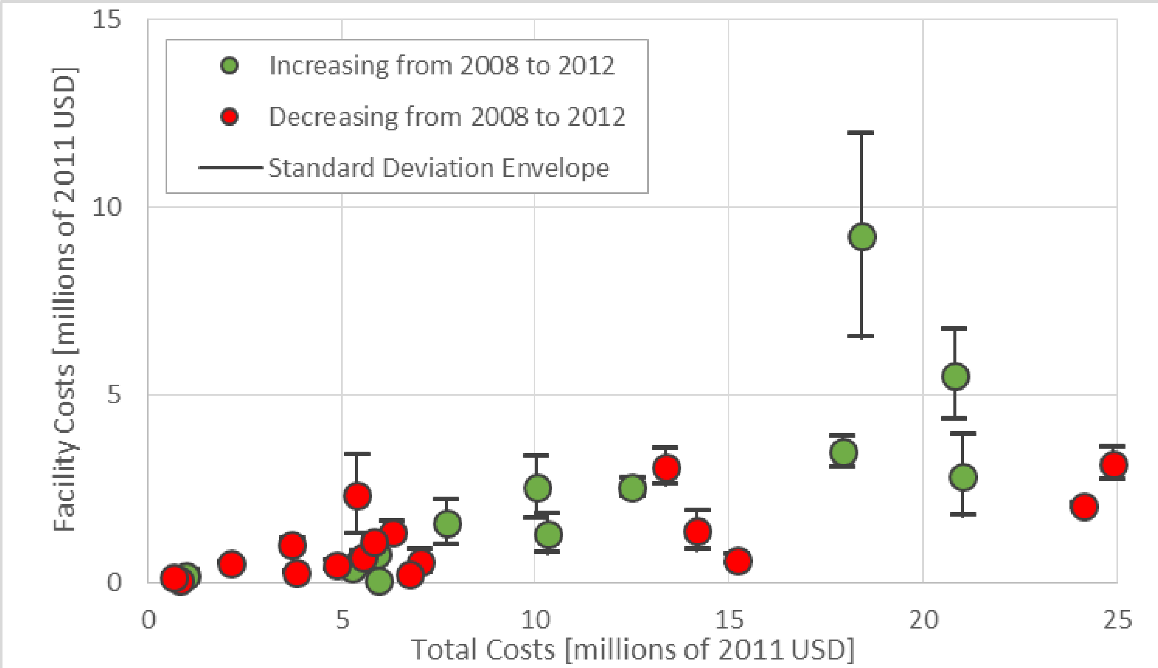
The variability evident in State-specific enforcement costs when disaggregating them into personnel and facilities costs constrains a meaningful analysis of trends. **Figure 2** and **Figure 3** depict this variability for personnel costs and facilities costs, respectively, in the 32 reporting States for 2008 through 2012. The figures plot the mean annual cost and the variability of these costs (in terms of the standard deviation evident from the data) over the 5 years. Comparing costs reported for 2008 and 2012 specifically, 20 of the 32 reporting States experienced an increase in personnel costs while 12 experienced a decrease. Similarly, for facilities costs, 14 of the 32 reporting States experienced a cost increase and 18 reported a cost decrease.

Figure 2: Mean Annual Personnel Costs and Variability by State: 2008 to 2012



Notes: The cost increases (depicted as green dots) and cost decreases (depicted as red dots) reflect cost changes between 2008 and 2012 only, and do not account for costs reported in 2009 through 2011. The costs plotted in the figure are for 30 of the 32 reporting States; two States have not been plotted because their costs exceed the scale of the figure. These two States reported an increase in personnel funding. One State had a mean total cost of $131 million and a mean personnel cost of $107 million with a standard deviation in personnel costs of $28.8 million over the 5 years. The other State had a mean total cost of $55 million and a mean personnel cost of $50 million with a standard deviation in personnel costs of $1.5 million over the 5 years. All cost figures are in 2011 USD.

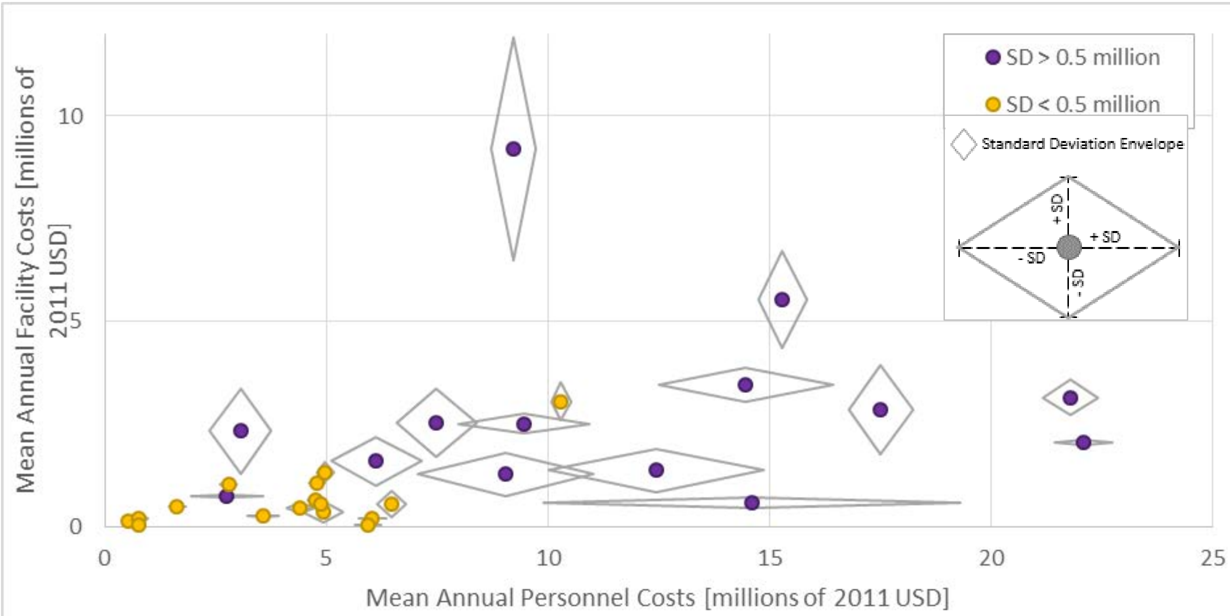
Figure 3: Mean Annual Facilities Costs and Variability by State: 2008 to 2012



Notes: The cost increases (depicted as green dots) and cost decreases (depicted as red dots) reflect cost changes between 2008 and 2012 only, and do not account for costs reported in 2009 through 2011. The costs plotted in the figure are for 30 of the 32 reporting States; two States have not been plotted because their costs exceeded the scale of the figure. One of these States reported an increase in facility funding, a mean total cost of $131 million, and a mean facility cost of $14 million with a standard deviation in facility costs of $12.3 million over the 5 years. The other State reported a decrease in facility funding, a mean total cost of $55 million, and a mean facility cost of $5 million with a standard deviation in facility costs of $0.1 million over the 5 years. All cost figures are in 2011 USD.

Figure 4 shows the data that are plotted separately in **Figure 2** and **Figure 3** in one graph to simultaneously reveal mean annual costs and cost variability for both personnel and facilities for the reporting States. Over the 5-year period, half of the States reported only minor changes (standard deviation less than $0.5 million) in personnel or facilities costs and most of these States have relatively low enforcement budgets. In contrast, higher variability tends to exist for those States with higher mean annual personnel or facilities costs. In these States, this variability is typically due to 1 or more years of markedly higher investments in the enforcement program.

Figure 4: Mean Annual Personnel and Facilities Costs and Cost Variability by State: 2008 to 2012



Notes: The costs plotted in the figure are for 30 of the 32 reporting States; two States have not been plotted because their costs exceeded the scale of the figure. One State has a mean annual facility cost of $14 million with a standard deviation of $12 million and a mean annual personnel cost of $107 million with a standard deviation of $28.8 million. The other State has a mean annual facility cost of $5 million with a standard deviation of $0.1 million and a mean annual personnel cost of $50 million with a standard deviation of $1.5 million. All cost figures are in 2011 USD.

Truck Weight Enforcement Scales

Beyond cost data, the quantity of weigh scales used in a State is another way of understanding the resource inputs for TSW enforcement programs. Nationwide, annual trends in the total reported number of weigh scales vary by weigh scale type. The SEPs contain statistics about four types of weigh scales, namely: fixed platform (static scales), portable scales, semi-portable scales, and weigh-in-motion (WIM) scales. A total of 50 States reported statistics about weigh scale usage each year, from 2008 to 2012, inclusive. **Table** 7 reveals the following:

- The number of fixed platform scales increased from 726 in 2008 to 822 in 2010 before levelling off and decreasing slightly to 817 in 2012.
- The number of portable scales increased each year from 2008 through 2012, rising from a total of 13,230 to 15,012. However, it appears that certain States may be reporting the actual number of portable scales in operation while others may be reporting the number of locations at which portable scales are used or even the number of weighings conducted with portable scales.
- The number semi-portable scales decreased from 238 in 2008 to 221 in 2012.

- The number of WIM scales used for TSW enforcement has increased each year from 2008 through 2012, rising from a total of 625 in 2008 to 793 in 2012. Within this period, the largest increase occurred from 2009 to 2010, when the number of WIMs increased by 10 percent.

Table 7: Quantity of Weigh Scales by Scale Type for all 50 Reporting States: 2008 to 2012

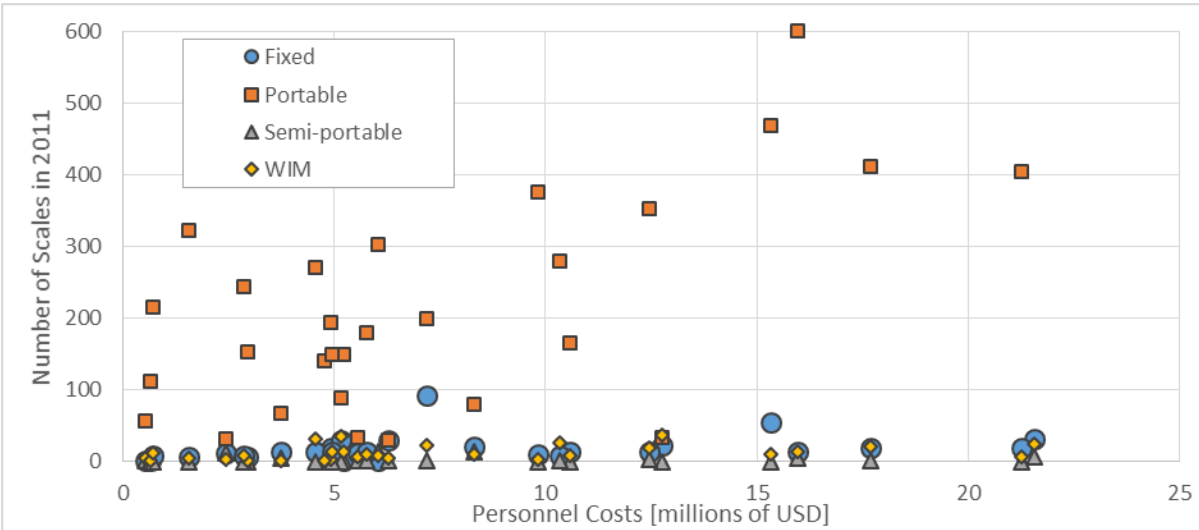
	Nationwide Number of Scales by Year *Percent Change of Scales from Previous Year*				
Scale type	**2008**	**2009**	**2010**	**2011**	**2012**
Fixed platform	726	772 *6%*	822 *6%*	822 *0%*	817 *-1%*
Portable	13,230	13,989 *5%*	14,656 *5%*	14,727 *<1%*	15,012 *2%*
Semi-portable	238	235 *-1%*	231 *-2%*	220 *-5%*	221 *0%*
WIM	625	679 *8%*	752 *10%*	782 *4%*	793 *1%*

State-level differences in the number of scales (by scale type) reported in 2008 and 2012 follow:

- Sixteen States reported an increase in the number of fixed platform scales, 13 reported a decrease, and 21 reported no change.
- Twenty-nine States reported an increase in the number of portable scales, 11 reported a decrease, and 10 reported no change.
- Nine States reported an increase in the number of semi-portable scales, 11 reported a decrease, and 30 reported no change.
- Twenty-six States reported an increase in the number of WIM scales, 5 reported a decrease, and 19 reported no change.

A State's investment in various types of weigh scales relates to the proportion of its total costs allocated to enforcement personnel. As shown in **Figure 5**, the quantity of portable scales used by a State is positively correlated with the State's personnel costs. This reflects the fact that weighings by portable scales require higher levels of personnel hours compared to weighings using the other types of weigh scales. Conversely, the quantity of fixed, semi-portable, and WIM scales in a State is relatively independent of the State's personnel costs.

Figure 5: Number of Weigh Scales by Scale Type as a Function of Personnel Costs: 2011



Nearly all (49 of 50) States report using a combination of weigh scales for truck weight enforcement. In the State where this is not the case, the strategy has been to move away from sites featuring traditional fixed infrastructure. Most fixed scales are located on Interstate highways near State and international border crossings. WIM scales are most often used for sorting or pre-screening at fixed scale locations, monitoring truck weights on scale bypass routes, and identifying potential violators for mobile operations where trucks detected as overweight by WIM scales are pulled over at pull-outs, safety rest areas, or other locations where portable scales can be safely used to conduct a static weighing. Although there is a movement to virtual weigh stations or virtual weighing technology in nearly all States, the definition of equipment and practices that define virtual weight enforcement varies.

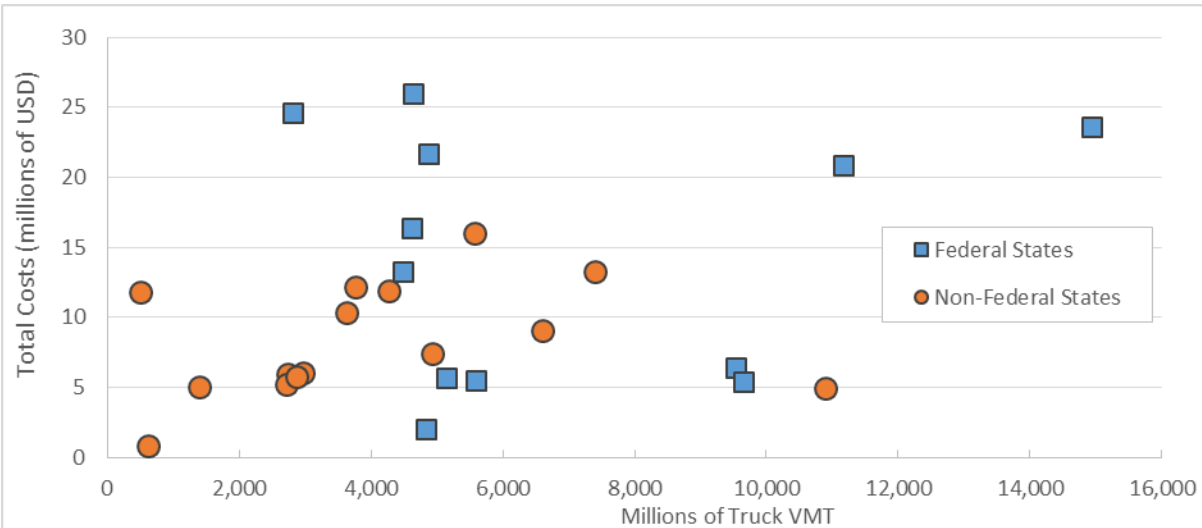
State-Level Comparative Analysis

Building on the foregoing analysis of enforcement program costs (inputs) at the national level, the State-level comparative analysis considers how enforcement costs and resources may differ between States that allow vehicles in excess of Federal truck weight limits (i.e., above-limit States) and States that do not allow vehicles in excess of Federal limits (i.e., at-limit States).

Figure 6 shows the total cost per VMT for the 29 analysis states in 2011 disaggregated into at-limit and above-limit categories (see **Table 3**). Cost differences between the at-limit and above-limit States are not readily apparent from the data. For the at-limit States, the total enforcement program cost ranges from $0.40 to $8.70 per thousand truck VMT, with a median cost of $1.80 per thousand truck VMT. Comparatively, for the above-limit States (excluding one outlying State), the total enforcement program cost ranges from $0.50 to $3.60 per thousand truck VMT, with a median cost of $2.00 per thousand truck VMT.

Based on this comparison, differences in enforcement costs normalized by VMT are not readily attributable to whether or not a State allows trucks to operate above Federal limits. Rather, differences in how States deliver enforcement programs (e.g., methods of enforcement used, intensity of enforcement) may be more influential on total costs. In addition, normalizing costs using VMT may elevate costs per VMT in States that have enforcement responsibilities for extensive highway networks with relatively low truck volume.

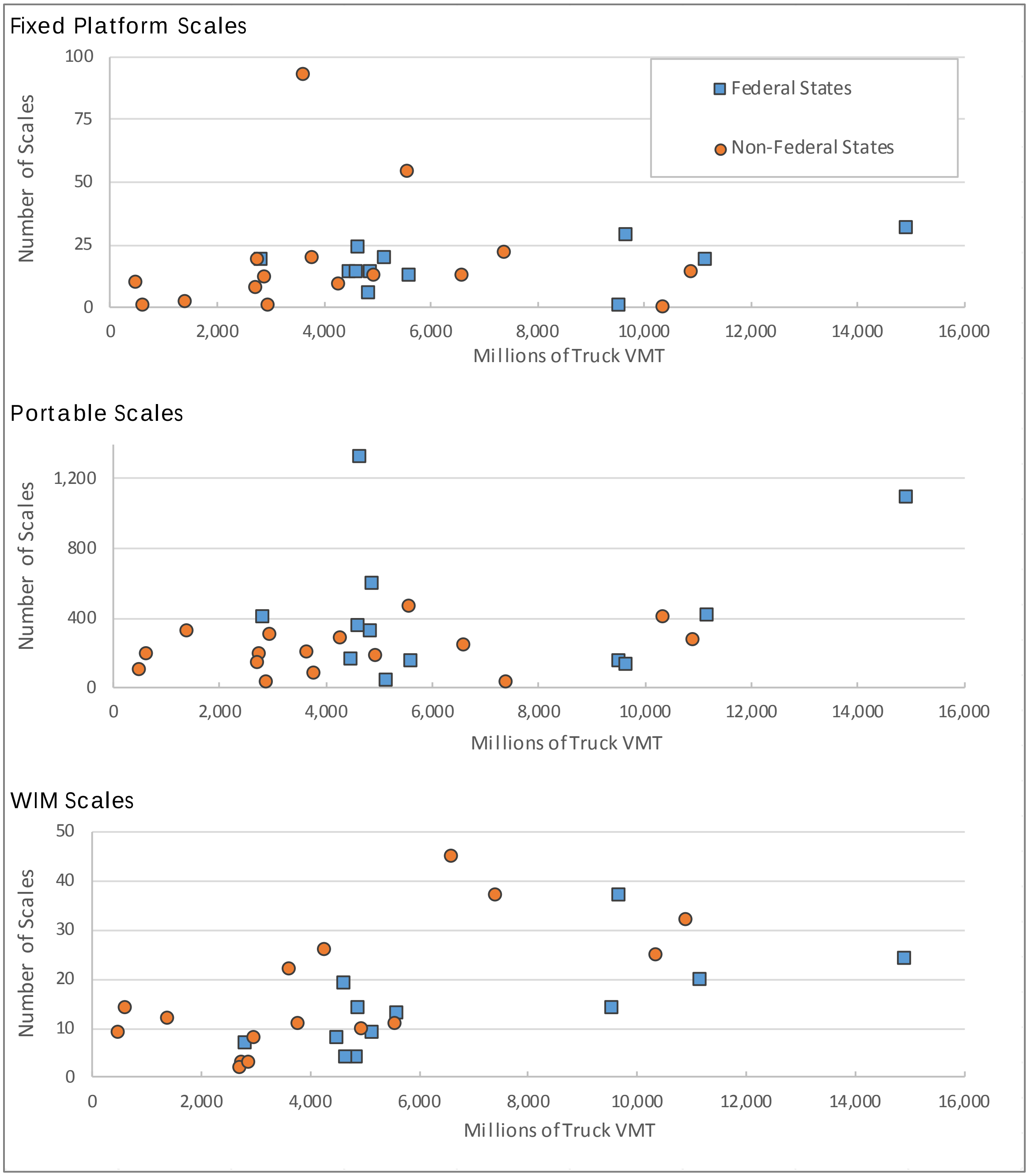
Figure 6: Total Enforcement Program Costs per Million Truck VMT: 2011



Notes: "Federal States" refers to States with maximum weight limits consistent with the 80,000 lb. Federal maximum GVW; these are also referred to as "at-limit States." "Non-Federal States" refers to States with maximum legal weight limits that exceed the Federal limits, also referred to as "above-limit States." The figure depicts enforcement program costs for 27 of the 29 analysis States. One at-limit State is not depicted in the figure due to scaling; this State has a truck VMT of 31,173 million and a total cost of $54.7 million. Cost data were unavailable for one above-limit State.

Figure 7 shows the total number of scales (for fixed, portable, and WIM scales) normalized by VMT for the 29 analysis States in 2011, disaggregated into the at-limit and above-limit categories. **Figure 7** does not include the quantity of semi-portable scales because the majority of States operated two or fewer semi-portable scales in 2011, and about 40 percent did not operate any.

Figure 7: Number of Weigh Scales per Million Truck VMT



Notes: "Federal States" refers to States with maximum weight limits consistent with the 80,000 lb. Federal maximum GVW; these are also referred to as "at-limit States." "Non-Federal States" refers to States with maximum legal weight limits that exceed the Federal limits, also referred to as "above-limit States." The figure depicts the number of scales for 28 of the 29 analysis States. One above-limit State is not depicted due to scaling; this State has a truck VMT of 31,173 million and 57 fixed platform, 1,800 portable, and 10 WIM scales.

The data plotted in the figure reveals the following:

- For fixed scales, there is effectively no difference in the median number of scales per truck VMT between at-limit and above-limit States. The median number of fixed scales per billion truck VMT for both the at-limit and above-limit categories is about three.
- For portable scales, there is effectively no difference in the median number of scales per truck VMT between at-limit and above-limit States. The median number of portable scales per billion truck VMT for at-limit States is about 58, compared to about 53 for above-limit States.
- For WIM scales, there is effectively no difference in the median number of scales per truck VMT between at-limit and above-limit States. The median number of WIM scales per billion truck VMT for at-limit States is about two, compared to about three for above-limit States.

Overall, the State-level comparative analysis of the number of weigh scales in use revealed no effective differences between at-limit and above-limit States. In other words, States which allow trucks to operate in excess of Federal limits did not exhibit a different weigh scale investment strategy than States that adopt Federal limits.

Truck Weight Enforcement Cost Comparisons for the Alternative Truck Configurations Introduced in the Scenario Analysis

The vehicle-specific comparative analysis provides a second way of revealing potential cost differences associated with enforcing truck weights for trucks that operate within Federal limits and trucks that operate beyond those limits. Specifically, this comparative analysis examines the time required to weigh the six alternative truck configurations and the two control vehicles being studied as a function of the type of weigh scale.

Table 8 provides the estimated weighing times for single-semitrailer trucks by scale type based on data gathered from commercial motor vehicle State enforcement officials. The following points summarize the key results from weighing single-semitrailer trucks:

- *Five-axle tractor semitrailer at 80,000 lb. (control vehicle)*: Officials indicate that it takes between 20 seconds and 15 minutes to weigh a five-axle tractor semitrailer (control vehicle) using a fixed weigh scale (where axles groups are weighed independently), up to about 1 minute using a fixed weigh bridge (which measures the whole vehicle), between 2 and 30 minutes using a portable scale, and between 3 and 30 minutes using a semi-portable scale. Mean weighing times for this vehicle are 4 minutes for a fixed (axle group) weigh scale (about 15 vehicles per hour), 1 minute for a fixed weigh bridge (about 60 vehicles per hour), 14 minutes for a portable scale (about 4 vehicles per hour), and 10 minutes for a semi-portable scale (about 6 vehicles per hour). Median weighing times for this vehicle are 2 minutes for a fixed (axle group) weigh scale, 1 minute for a fixed weigh bridge, 15 minutes for a portable scale, and 4 minutes for a semi-portable scale.
- *Five-axle tractor semitrailer at 88,000 lbs.*: There is no incremental impact on weighing times for a five-axle tractor semitrailer at 88,000 lb. GVW relative to a five-axle tractor semitrailer at 80,000 lb. GVW (control vehicle) on any type of weigh scale.

- *Six-axle tractor semitrailers at 91,000 lb. or 97,000 lbs.*: The incremental differences in weighing times between the five-axle tractor semitrailer (control vehicle) and the six-axle tractor semitrailer are independent of the GVW on the six-axle tractor semitrailer (either 91,000 lb. or 97,000 lb.). In other words, the incremental differences are evident because of the extra axle, not the change in GVW. Officials indicate that it takes between 20 seconds and 15 minutes to weigh a six-axle tractor semitrailer using a fixed (axle group) weigh scale, up to about 1 minute using a fixed weigh bridge, between two and 40 minutes using a portable scale, and between 3 and 35 minutes using a semi-portable scale. There is no difference in the mean or median weighing times between the six-axle tractor semitrailer and the control vehicle for the fixed (axle group) weigh scale and fixed weigh bridge. This implies that the officials providing the data assumed that the length of the fixed (axle group) weigh scales is sufficient to accommodate a tridem axle group. For portable scales, the mean time to weigh a six-axle tractor semitrailer is 17 minutes, compared to 15 minutes for the control vehicle (there is no change in median time). For semi-portable scales, the mean time to weigh a six-axle tractor semitrailer is 11 minutes, compared to 10 minutes for the control vehicle (there is no change in median time).

Table 8: Estimated Weighing Time for Single-Semitrailer Trucks by Scale Type

	Estimated Weighing Time (minutes) by Scale Type[1]											
	Fixed weigh scale (weighs axle groups)			Fixed weigh bridge (weighs vehicle)			Portable scale			Semi-portable scale		
Alternative Configuration	Range	Mean	Median	Range	Mean	Median	Range	Mean	Median	Range	Mean	Median
Control Vehicle												
 3-S2 @ 80K lb. (53')	<1-15	4	2	<1-1	1	1	2-30	14	15	3-30	10	4
 3-S2 @ 88K lb. (53')	–	–	–	–	–	–	–	–	–	–	–	–
 3-S3 @ 91K lb. (53')	–	–	–	–	–	–	2-40	17	15	3-35	11	4
 3-S3 @ 97K lb. (53')	–	–	–	–	–	–	2-40	17	15	3-35	11	4

– The weighing time(s) are identical to those given for the control vehicle.
[1] Estimates are obtained from commercial motor vehicle State enforcement officials.

Table 9 provides the estimated weighing times for multiple-trailer trucks by scale type. The following points summarize the key findings about weighing multiple-trailer trucks:

- *Five-axle tractor semitrailer with two 28.5-ft.trailers at 80,000 lbs. (control vehicle)*: Officials indicate that it takes between 20 seconds and 15 minutes to weigh a five-axle tractor semitrailer-trailer (control vehicle) using a fixed weigh scale (where axles groups are weighed independently), up to about 1 minute using a fixed weigh bridge (which measures the whole vehicle), between 3 and 40 minutes using a portable scale, and between 4 and 30 minutes using a semi-portable scale. Mean weighing times for this vehicle are 4 minutes for a fixed (axle group) weigh scale (about 15 vehicles per hour), 1 minute for a fixed weigh bridge (about 60 vehicles per hour), 17 minutes for a portable scale (about four vehicles per hour), and 10 minutes for a semi-portable scale (about six vehicles per hour). Median weighing times for this vehicle are 3 minutes for a fixed (axle group) weigh scale, 1 minute for a fixed weigh bridge, 15 minutes for a portable scale, and 5 minutes for a semi-portable scale.
- *Five-axle tractor semitrailer with two 33-ft trailers at 80,000 lbs.*: Officials indicate that it takes between 20 seconds and 15 minutes to weigh a five-axle tractor semitrailer-trailer (2 @ 33 ft.) using a fixed (axle group) weigh scale, up to about 2 minutes using a fixed weigh bridge, between 4 and 40 minutes using a portable scale, and between 4 and 35 minutes using a semi-portable scale. There is no difference in the mean or median weighing times between the five-axle tractor semitrailer-trailer (2 @ 33 ft.) and the control vehicle for the fixed weigh bridge and the portable scale. For fixed (axle group) scales, the mean time to weigh a five-axle tractor semitrailer-trailer (2 @ 33 ft.) is 5 minutes, compared to 4 minutes for the control vehicle (there is no change in median time). For semi-portable scales, the mean time to weigh a five-axle tractor semitrailer-trailer (2 @ 33 ft.) is 12 minutes, compared to 10 minutes for the control vehicle (there is no change in median time).
- *Seven- and nine-axle triple trailer combinations*: Three of the seven officials provided estimates of weighing times for the two triple trailer combinations; thus, the table does not provide the reported range in weighing times or the mean and median weighing times. Rather, the table provides an estimated mean weighing time based on the responses provided and an understanding of how the various weigh scales operate. For fixed (axle group) scales, it takes about 6 minutes to weigh either triple trailer combination, compared to 4 minutes for the control vehicle. This estimated mean is calculated by assuming that the time to weigh an axle group on the control vehicle is the same as the time to weigh an axle group on the triple trailer combinations. For portable scales, it takes about 23 minutes to weigh the seven-axle triple trailer combination and about 30 minutes to weigh the nine-axle triple trailer combination, compared to 17 minutes for the control vehicle. These estimated means are calculated by assuming that the time to weigh an axle on the control vehicle is the same as the time to weigh an axle on the triple trailer combinations. For semi-portable scales, it takes about 14 minutes to weigh the seven-axle triple trailer combination and about 19 minutes to weigh the nine-axle triple trailer combination, compared to 10 minutes for the control vehicle. These estimated means are calculated by assuming that the time to weigh an axle on the control vehicle is the same as the time to weigh an axle on the triple trailer combinations.

Table 9: Estimated Weighing Time for Multiple-Trailer Trucks by Scale Type

	Estimated Weighing Time (minutes) by Scale Type [1]											
	Fixed weigh scale (weighs axle groups)			Fixed weigh bridge (weighs vehicle)			Portable scale			Semi-portable scale		
Alternative Configuration	Range	Mean	Median	Range	Mean	Median	Range	Mean	Median	Range	Mean	Median
Control Vehicle  2-S1-2 @ 80K lb. (2 @ 28.5’)	<1-15	4	3	<1-1	1	1	3-40	17	15	4-30	10	5
 2-S1-2 @ 80K lb. (2 @33’)	–	5	–	<1-2	–	–	4-40	–	–	4-35	12	–
 2-S1-2-2 @ 105K lb. (3 @ 28.5’)	*	6[2]	*	*	*[3]	*	*	23[4]	*	*	14[4]	*
 3-S2-2-2 @ 129K lb. (3 @ 28.5’)	*	6[2]	*	*	*[3]	*	*	30[4]	*	*	19[4]	*

– Weighing time(s) are identical to those given for the control vehicle.
* No data were provided.
[1] Estimates (except for triple trailer combinations) are obtained from commercial motor vehicle State enforcement officials.
[2] The estimated mean is calculated by assuming that the time to weigh an axle group on the control vehicle is the same as the time to weigh an axle group on the triple trailer combinations.
[3] For fixed weigh bridges, assuming that the weigh bridge is long enough to weigh the entire vehicle, there would be no incremental weighing time required to weigh a triple trailer combination compared to the control vehicle. However, since weigh bridges may not have adequate length capacity, there may be a need to retrofit these sites to accommodate longer vehicles. Alternatively, there may be opportunities for States to measure GVW by summing individually measured axle group weights. This method of measuring GVW has been adopted in certain States, but is not currently accepted universally.
[4] The estimated mean is calculated by assuming that the time to weigh an axle on the control vehicle is the same as the time to weigh an axle on the triple trailer combinations.

Based on the nine-step procedure and assumptions described in **Section 2.2**, the mean incremental weighing times reported in the foregoing tables were used to estimate the system-wide impacts on enforcement personnel costs caused by the introduction of the alternative truck configurations defined by the six scenarios. **Table 10** summarizes the results of the scenario analysis. The table shows decreases in personnel costs for all six scenarios relative to the base case personnel costs. The magnitudes of these decreases range from 0.3 percent (Scenario 1) to 1.1 percent (Scenario 4). Experiential data from State TSW enforcement officials support these results, as no indication was given that a change in the types of trucks in the traffic stream would impact system-wide enforcement costs. In all scenarios, personnel costs decrease because the reduction in VMT (particularly for the five-axle truck configurations) predicted by the scenarios outweighs the increased costs associated with weighing the alternative truck configurations. Viewed another way, the rate at which weighings occur (per VMT) or the time spent conducting a weighing could be increased under the scenario conditions for the same level of expenditures on enforcement personnel.

Table 10: Results of Enforcement Cost Scenario Analysis

	Personnel Costs[1] [2011 USD]			
Scenario	**Base Case**	**Scenario**	**Absolute Difference [2011 USD]**	**Percent Change [%]**
Scenario 1	$ 490,002,480	$ 488,523,723	-$ 1,478,757	**-0.3**
Scenario 2	$ 490,002,480	$ 487,870,549	-$ 2,131,931	**-0.4**
Scenario 3	$ 490,002,480	$ 484,999,852	-$ 5,002,628	**-1.0**
Scenario 4	$ 490,002,480	$ 484,776,197	-$ 5,226,283	**-1.1**
Scenario 5	$ 490,002,480	$ 486,382,715	-$ 3,619,766	**-0.7**
Scenario 6	$ 490,002,480	$ 486,431,910	-$ 3,570,571	**-0.7**

[1] The personnel costs shown in the table are summed for the 44 States that reported personnel (non-zero) costs in 2011.

If enforcement personnel expenditures were to remain constant under the scenario conditions, the reduction of truck VMT may enable an increase in the number of non-WIM weighings that could be conducted. (Chapter 3 provides a detailed discussion of national-level truck weighing trends). **Table 11** shows the number of non-WIM weighings for base case and scenario traffic conditions and the additional number of non-WIM weighings that could be performed for each scenario given the personnel cost savings estimated for the scenarios. These estimates assume that the proportion of weighings by weighing method remains constant for all relevant truck configurations within each scenario. Depending on the scenario, the number of additional non-WIM weighings that could be conducted nationwide ranges from nearly 200,000 (Scenario 1) to over 600,000 (Scenarios 3 and 4).

Table 11: Additional Non-WIM Weighings that Could Be Conducted Given Personnel Cost Savings by Scenario

	2011 Non-WIM Weighings[1]		
Scenario	**Base Case**	**Scenario**	**Additional Non-WIM Weighings**
Scenario 1	28,310,492	28,122,926	187,566
Scenario 2	28,887,786	28,625,608	262,178
Scenario 3	28,887,786	28,256,956	630,830
Scenario 4	29,274,235	28,653,878	620,356
Scenario 5	29,370,253	28,982,788	387,466
Scenario 6	29,274,239	28,872,395	401,843

[1]Non-WIM weighings are trucks weighed on portable, semi-portable and static scales.

Translating enforcement personnel cost savings into additional weighings is one option that may impact enforcement program effectiveness. However, other alternatives and issues also warrant consideration.

- *Technologies*: This report documents numerous technologies designed to automate truck weighing and inspection procedures. Many of these technologies offer opportunities to increase the number of weighings without relying on traditional on-road enforcement methods.
- *Current enforcement program status*: The option of weighing additional trucks may not be equally appropriate for all States, depending on the current status of a State's enforcement program. As will be discussed in Chapter 3, States that already achieve a certain level of enforcement intensity (i.e., weighings per truck VMT) may be unlikely to gain additional benefit by further intensifying enforcement. The opposite may be true for States with relatively low enforcement intensity. However, it is not only the quantity of weighings that impacts enforcement effectiveness but also the method used to conduct the weighing (i.e., fixed, portable, semi-portable). Thus, both the number of weighings and the method by which these weighing occur influence enforcement resource allocation strategies.
- *Local conditions*: Existing and future weighing strategies used by an enforcement agency depend on a host of local conditions, including the extent and nature of the road network, the types of industries operating in a region, the types of commodities being hauled, and the types of truck configurations being used.

The State commercial motor vehicle enforcement officials also provided estimates of weighing times for WIM devices, including those used as a component of a virtual weigh scale. These estimates show that the weighing time for a WIM scale is on the order of a few seconds and does not vary appreciably for different vehicle configurations. The weighing capacity of a WIM effectively varies only by the vehicle speed, which is influenced by the location of the WIM (i.e., on a pre-screening ramp or on the mainline) and factors associated with traffic operations.

In addition to the impacts on weighing times, the introduction of the alternative truck configurations may necessitate costs associated with equipment, information technology, and human resources. Equipment costs that may be incurred include the potential need to upgrade fixed facilities to enable weighing of longer truck configurations. There may also be requirements to purchase additional equipment for officers using portable weigh scales. From an information technology perspective, there may be a need to re-program existing screening algorithms. The level of effort associated with this activity can range from minimal (less than a half-hour) to several hours, depending on whether a site is accessible remotely or requires staff to be onsite to update the equipment. Automated permitting systems may also require reconfiguring. Finally, there may be incremental costs associated with re-training of both the enforcement community and the industry as well as costs associated with concomitant revisions to training and educational materials.

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CHAPTER 3 – COMPLIANCE EFFECTIVENESS OF ENFORCEMENT

3.1 Scope

This chapter documents the results from the *effectiveness of enforcement* analysis. The purpose of this work is to compare the effectiveness of enforcing TSW limits for trucks operating at or below current Federal truck weight limits and trucks operating above those limits. Specifically, the objectives of the work are to:

- Analyze effectiveness at the national level in terms of enforcement program outputs (e.g., weighings, citations) and pertinent relationships between certain outputs and the program inputs discussed in **Chapter 2**;
- Analyze truck size and weight enforcement effectiveness for States where trucks operate above Federal limits as compared with enforcement effectiveness among States that adopt Federal truck weight limits; and
- Analyze effectiveness by assessing compliance outcomes for the alternative truck configurations and estimate these outcomes for the scenarios.

In addition, this work identifies statutes and regulations pertaining to Federal truck size and weight limits that would be impacted in the event of changes to these limits. These impacts are summarized at the end of **Section 3.3**, with details provided in **Appendix D**.

The scope of analysis for this work is constrained as follows:

- The base analysis year for the 2014 CTSW Study is 2011. To capture annual trends in enforcement program outputs, the analysis includes data reflecting program inputs and outputs from 2008 through 2012, thereby using the most current, reliable data available.
- This work focuses on effectiveness related to enforcing truck weight; less emphasis is placed on truck size enforcement.
- The work supports the comparative analysis of commercial motor vehicles that operate at or below 80,000 pound gross vehicle weight, 20,000 pound single axle weight, 34,000 pound tandem axle weight, and at or below weight limits as calculated through the Federal Bridge Formula as provided in Title 23 of the United States Code under Section 127. Exemptions to the size and weight limits stated and provided in 23 USC Section 127 that allow alternative configuration characteristics are to be treated as "vehicles operating in excess of Federal size and weight limits." Similarly, vehicles operating under a State-issued permit, including all divisible or non-divisible load movements, are to be treated as "vehicles operating in excess of Federal size and weight limits."

For the purposes of this work, the following terms are defined:

- *Weighing*: A weighing is the process of using a certified weight measuring device to assess a commercial motor vehicle being used for highway transport for compliance with applicable commercial motor vehicle weight regulations. A weighing may be conducted statically or dynamically.

- *Weight violation*: A weight violation occurs when a commercial motor vehicle being used for highway transport is found to be in non-compliance with one or more of the weight regulations governing commercial motor vehicle operations. A weight violation may or may not lead to the issuance of a weight citation, as a vehicle may be brought into compliance by offloading or load shifting. The industry and the literature frequently use the terms "violation" and "citation" interchangeably.
- *Weight citation*: A weight citation occurs when a legal summons is issued due to the observance of one or more weight violations.
- *Weight-compliant event:* A weight-compliant event occurs when a commercial motor vehicle being used for highway transport is subject to a weighing and is found to be in compliance with all weight regulations governing commercial motor vehicle operations.

3.2 Methodology

As described in **Chapter 1**, enforcement program effectiveness is considered in terms of outputs and outcomes within the performance-based approach applied in this study. Within the context of this over-arching study approach, this section provides specific details about the methodology and data applied for each of the three objectives. The methodology applied in this study extends the results of the previous 2000 CTSW Study (see U.S. Department of Transportation 2000) in three main ways. First, it provides an updated analysis of enforcement program activities (i.e., outputs) at the national level. Second, it establishes output-based relationships that can be used to describe and compare enforcement program effectiveness. Finally, it analyzes WIM data to assess truck weight compliance for the alternative truck configurations and uses the results of this assessment to estimate the compliance impacts of introducing these configurations into the traffic stream.

National-Level Output Trends and Relationships

The measures of enforcement program output included in this component of the analysis are the number of truck weighings (by type of weighing method), citations (by type of citation), load shifting and off-loading requirements, and permit issuance activities. In addition, the analysis develops three pertinent output-based relationships of enforcement effectiveness: weighing cost-efficiency, citation rate, and citation rate as a function of enforcement intensity. Another relationship that could provide an output-based understanding of enforcement effectiveness is the impact that the level of sanctions (or severity of the penalty) has on the number of citations. For example, to reduce the number of citations, it may be more effective to increase the amount of fines violators are subject to rather than increase the intensity of enforcement by weighing more vehicles. Investigation of this relationship, however, is beyond the scope of this study.

The Annual Certifications of Truck Size and Weight Enforcement database contains data reported by States for each of these output measures and is the primary data source used to analyze enforcement program outputs. Data from 2008 to 2012 are included in the analysis. The following limitations apply to the data:

- The Federal regulations that require States to certify the enforcement of Federal truck size and weight laws do not explicitly define the vehicles that fall within the scope of

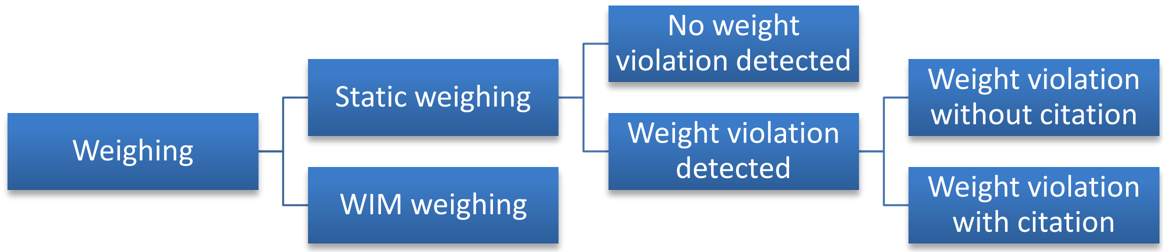
TSW enforcement activities. It is understood, however, that the types of vehicles included in the scope of TSW enforcement activities generally coincide with the definition of a commercial motor vehicle. According to the 23 CFR Part 658, a commercial motor vehicle is "a motor vehicle designed or regularly used to carry freight, merchandise, or more than ten passengers, whether loaded or empty, including buses, but not including vehicles used for vanpools, or recreational vehicles operating under their own power." [3] While this definition includes passenger-carrying vehicles, these represent a negligible proportion of vehicles subject to weighings in most States. In fact, passenger-carrying vehicles are generally not required to stop at weigh stations simply because they have passengers on board and there is concern with delaying the passengers. In addition, some States may include recreational vehicles and various types of light duty trucks within the scope of their weight enforcement activities. For these reasons, there may be inconsistencies in the data submitted by the States.

- The Federal regulations that require States to certify the enforcement of Federal truck size and weight laws do not provide a clear distinction between violations and citations. As defined earlier, it is impossible to have a citation without a violation. However, a vehicle found to be in violation may result in a citation, multiple citations (corresponding to multiple violations), or no citations. The regulations themselves also appear to use the terms "violation" and "citation" interchangeably. For these reasons, there may be inconsistencies in the data submitted by the States.
- The Federal regulations that require States to certify the enforcement of Federal truck size and weight laws do not specify whether the reported number of weighings by WIMs should include only those WIMs used within a State's TSW enforcement program, or also WIMs used within a State's traffic monitoring program. It is generally understood that most States only report weighings by WIMs used specifically for TSW enforcement purposes.
- None of the data contained in the Annual Certifications of Truck Size and Weight Enforcement database can be disaggregated by truck configuration. This precludes the analysis of weighings and citations for the specific control vehicles and alternative truck configurations of interest in the 2014 CTSW Study. The citations recorded in the database cannot be attributed to a specific enforcement method (i.e., fixed, portable), industry, commodity, or time period (other than calendar year). In addition, the actual axle or gross vehicle loads that triggered the issuance of a citation, shifting of the load, or off-loading are not recorded.

Figure 8 provides a diagrammatic view of how weighings lead to citations, which are ultimately recorded in the Annual Certifications of Truck Size and Weight Enforcement database. There are two types of weighings: those that occur while the vehicle is stopped (i.e., static weighings at fixed, portable, or semi-portable scales) and those that occur while the vehicle is in motion (i.e., dynamic weighings at WIM sites).

[3] The term "buses" used in this context is normally understood to mean over-the-road buses involved in the inter-city transport of passengers as opposed to municipal public transit vehicles.

Figure 8: Weighings, Weight Violations, and Weight Citations



Currently, WIM weighings are not used to directly enforce truck weight in the United States, though they are an important component of the weight enforcement process. Some fixed truck weight and inspection sites have sorter lanes that all trucks are required to follow. The sorter lanes include WIM devices that have computer software capable of alerting a law enforcement officer monitoring the equipment when a truck exceeds axle, gross weight, or bridge formula requirements. The officer will direct the truck exceeding one or more of the weight parameters to a fixed static scale to verify the weight identified by the WIM device. Some WIM devices are also used for truck weight enforcement on the open highway. When a WIM device identifies that a passing truck exceeds its weight requirements, the device signals an enforcement response. Law enforcement personnel will track the truck and either direct the truck to a site where portable scales can be deployed or to a fixed weigh site to verify the weight.

While direct enforcement using WIM remains a goal for some jurisdictions, there are technological and legal issues associated with issuing a citation based on the comparison of a dynamically measured weight and a static weight limit. Thus, only static weighings result in the detection of weight violations that can be issued a citation.

A static weighing has two possible outcomes: either no weight violation is detected and the vehicle is deemed to be weight compliant, or at least one type of weight violation (axle, gross, or bridge formula) is detected and the vehicle is deemed to be weight non-compliant. The subset of vehicles deemed to be in violation (weight non-compliant) may then be required to offload, have load adjustments made, or may be issued a citation and be placed out of service until other equipment can be summoned to take part of the load. Thus, while the issuance of a citation can only take place following the (static) detection of a weight violation, not all weight violations lead to citations if the vehicle is brought into compliance by offloading or load shifting. Further, as noted earlier, there may not be a one-to-one relationship between weight citations and weight violations, as a single citation may be issued for a single weight violation or may represent multiple weight violations on the same vehicle.

State-Level Comparative Analysis

This component of the analysis for this work compares the effectiveness of TSW enforcement programs for States that allow vehicles in excess of Federal truck weight limits (i.e., above-limit States) and States that do not allow vehicles in excess of Federal limits (i.e., at-limit States). For this comparison, the relationship between citation rate and enforcement intensity is examined separately for at-limit and above-limit States with the aim of determining whether differences in this relationship are apparent at the State level. As such, this comparison can be understood as a way of revealing potential variations in enforcement effectiveness based on vehicle-specific differences. As with the cost analysis, the designation of States as at-limit and above-limit considers three information sources:

- Relevant TSW regulations pertaining to single-semitrailer and multiple trailer trucks operating in each State (e.g., 23 CFR 658, Appendix C) indicate whether a State may be effectively at-limit or above-limit. For example, States that routinely permit triple trailer combinations on Interstate highways may be designated as above-limit States.
- Estimated 2011 vehicle-miles traveled (VMT) for the scenarios' alternative truck configurations (e.g., six-axle tractor semitrailers, triple trailer combinations) provides an indication of the extent above-limit trucks operate in a State by highway network type. For example, States where six-axle semitrailers commonly operate above 80,000 lb. GVW (other than those where a single-trip permit may be required) may be designated as above-limit.
- Insights from commercial motor vehicle State enforcement officials provide an experiential indication of whether a State may be designated as at-limit or above-limit.

As such, this comparison does not account for State-specific variations in enforcement program delivery and permitting activities, nor does it fully consider the extent to which each truck configuration is allowed to operate within a State. Nevertheless, the comparison provides a pragmatic approach for identifying potential differences in enforcement program effectiveness associated with enforcing different types of truck configurations.

The scope of the comparative analysis includes the 29 comparison States, although specific State names are withheld. Based on these information sources for the purpose of this comparative analysis, 13 of the 29 comparison States are designated as at-limit and 16 as above-limit. As indicated earlier, the 29 comparison States were selected because they: (1) are considered to be enforcement programming leaders in the Nation; (2) have experience in enforcing vehicles subject to grandfather provisions (e.g., longer combination vehicles); or (3) have recently undertaken research and development projects related to TSW enforcement. In addition, the selection of these States considered the need to represent general variations in trucking operations across the Nation (e.g., configurations in use, industries served) and geographic factors.

Assessment of Compliance Outcomes for the Alternative Truck Configurations

Beyond the analysis of outputs, enforcement effectiveness can also be understood in terms of enforcement program outcomes. This component of the work assesses truck weight compliance outcomes (in terms of the proportion of weight-compliant observations and the severity of overweight observations) at a vehicle-specific level using WIM data at selected locations. Comparing the distributions of axle and gross vehicle loads with static weight limits enables the assessment of truck weight compliance for certain control and alternative truck configurations. The following paragraphs describe the data and methodology applied for these comparisons.

Weigh-in-motion devices measure the axle weights (and by summing these, the GVW), the spacing of these axles, and speed of a passing vehicle without requiring the vehicle to stop.

Extensive deployment of WIM systems throughout the United States for both enforcement purposes and transportation planning and engineering functions (e.g., pavement and bridge design) has resulted in a rich, often continuous information source about truck operations over extensive highway networks. Because WIM measurements are dynamic, they currently do not provide sufficient grounds for issuing a legal citation for operating an overweight commercial vehicle in the United States. Nevertheless, WIM devices play a role in the effectiveness of truck weight enforcement by providing a screening mechanism that reduces the number of trucks that must be targeted for static weighings.

As described in **Chapter 2**, the most common technologies used in WIM devices are piezoelectric sensors, piezoquartz sensors, bending plates, and single load cells. The accuracy of the weights measured by a WIM device varies by the type of technology as well as a number of installation, calibration, and environmental factors. According to ASTM E1318-09 (ASTM International, 2009), depending on the intended function of the WIM, a properly installed and calibrated WIM device should provide load measurements (95 percent of the time):

- Between ±15 percent and ±30 percent relative to a reference value for axle loads;
- Between ±10 percent and ±20 percent relative to a reference value for axle group loads; and
- Between ±6 percent and ±15 percent relative to a reference value for gross vehicle loads.

The Federally managed WIM database comprises State data submitted monthly to the Federal Highway Administration (FHWA). These State submissions for 2011 are the source of the WIM data used in the compliance assessment. The Study directs a comparative analysis of the weight compliance for control vehicles currently in widespread operation across the United States relative to alternative truck configurations (with specified axle configurations, GVW limits, and trailer lengths). Thus, the compliance assessment requires WIM data obtained from sites at which both a control vehicle and an alternative truck configuration are currently operating. This requirement is the primary criterion applied to determine the eligibility of WIM sites included in the compliance assessment. In addition to this primary criterion, several other factors were considered in the selection of WIM sites for the compliance assessment, but their influence was not quantified or fully controlled:

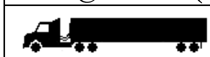
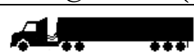
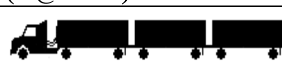
- The weights measured by a WIM device in close proximity to a fixed weigh scale or other locations subject to frequent or intense weight enforcement activity may be influenced by the presence of this activity. This influence may vary temporally and by highway functional class.
- The weights measured by a WIM device located on a portion of a highway network in a particular State in which alternative truck configurations operate may be influenced by weight limits in neighboring States if the neighboring State prohibits or restricts these configurations. The same type of influence could be present at WIM sites located near urban areas if special prohibitions or restrictions exist for specific configurations in that urban area.
- The types of industries that generate the demand for truck travel vary geographically and temporally. The specific characteristics of the commodities generated by these industries

influence the weights measured by WIMs in those regions. In addition, at certain locations, special weight allowances exist for trucks hauling certain types of commodities.

- Trucks operating under special permit may be more likely to operate on certain routes than others, but cannot be identified within the WIM database. Because these vehicles are subject to higher weight limits, their presence in the traffic stream influences the WIM measurements used in this compliance assessment if they operate with the same configuration as the control vehicles or alternative truck configurations being examined.

Table 12 lists the vehicle-specific comparisons and indicates whether or not the comparison is included in the compliance assessment. As shown in the table, the assessment includes two comparisons involving single-semitrailer trucks.

Table 12: Vehicle-specific Comparisons within the Compliance Assessment

Control Vehicle	Alternative Configuration	Scenario Included in Assessment?	Explanatory Notes
 3-S2 @ 80K lb. (53')	 3-S2 @ 88K lb. (53')	Scenario 1 not included.	It is not possible to distinguish the subset of 3-S2s that would be subject to the higher GVW limit.
 3-S2 @ 80K lb. (53')	 3-S3 @ 91K lb. (53')	Scenario 2 included.	The assessment uses WIM data from Washington.
 3-S2 @ 80K lb. (53')	 3-S3 @ 97K lb. (53')	Scenario 3 included.	The assessment uses WIM data from Maine.
 2-S1-2 @ 80K lb. (2 @ 28.5')	 2-S1-2 @ 80K lb. (2 x 33')	Scenario 4 not included.	The alternative configuration is not currently used in the United States.
 2-S1-2 @ 80K lb. (2 @ 28.5')	 2-S1-2-2 @ 105.5K lb. (3 @ 28.5')	Scenario 5 included.	The assessment uses WIM data from Oregon.
 2-S1-2 @ 80K lb. (2 @ 28.5')	 2-S1-2-2 @ 129K lb. (3 @ 28.5')	Scenario 6 included.	The alternative configuration used in this comparison is not the same as the vehicle defined by the scenario analysis (i.e., the 3-S2-2-2), which is currently relatively uncommon. The assessment uses WIM data from Nevada and Utah.

- *Five-axle tractor semitrailer (53 ft.) at 80,000 lbs. (control vehicle) and the six-axle tractor semitrailer (53 ft.) at 91,000 lb*: This comparison (Comparison 1) uses WIM data from the State of Washington. **Table 13** provides the details on the applicable axle weight and GVW limits in Washington. The GVW limit for six-axle tractor semitrailers is controlled by the bridge formula but would typically be limited to 92,000 lb. This differs slightly from the GVW limit for the alternative configuration, but is not expected to influence the comparative compliance assessment.

- *Five-axle tractor semitrailer (53 ft.) at 80,000 lbs. (control vehicle) and six-axle tractor semitrailer (53 ft.) at 97,000 lbs*: This comparison uses WIM data from Maine and comprises two components: data from the Interstate System (Comparison 2a) and data from off the Interstate System (Comparison 2b). **Table 13** provides the details on the applicable axle weight and GVW limits in Maine. Comparisons 2a and 2b account for the differences between the tandem axle weight limits on and off the Interstates. The GVW limit for six-axle tractor semitrailers is 100,000 lbs., which differs from the GVW limit for the alternative configuration; however, this difference is not expected to influence the comparative compliance assessment.

Table 13: Weight Limits for the Single-Semitrailer Truck Configurations Included in the Compliance Assessment

	Weight Limits on Interstate (pounds)			**Weight Limits off Interstate** (pounds)		
State and Configuration	**Tandem Axle**	**Tridem Axle**	**GVW**	**Tandem Axle**	**Tridem Axle**	**GVW**
Comparison 1 (Washington)						
Control Vehicle  3-S2 @ 80K lb. (53’)	34,000	n/a	Bridge formula (typically 80,000)	34,000	n/a	Bridge formula (typically 80,000)
Alternative Configuration  3-S3 @ 91K lb. (53’)	34,000	Bridge formula (typically 45,000) [1]	Bridge formula (typically 92,000)	34,000	Bridge formula (typically 45,000) [1]	Bridge formula (typically 92,000)
Comparisons 2a and 2b (Maine)						
Control Vehicle  3-S2 @ 80K lb. (53’)	34,000	n/a	80,000	38,000	n/a	80,000
Alternative Configuration  3-S3 @ 97K lb. (53’)	44,000 [2]	54,000 [3]	100,000	44,000 [2]	54,000 [3]	100,000

[1] In Washington State, a typical tridem axle has a maximum 12-ft spread and is therefore limited to 45,000 pounds by the bridge formula.
[2] This limit applies for certain commodities. The tandem axle weight limit for other commodities is 41,000 lb.
[3] This limit applies for certain commodities. The tridem axle weight limit for other commodities is 48,000 lb.

As shown in **Table 14**, the assessment also includes two comparisons involving multi-trailer trucks.

- *Five-axle tractor semitrailer with two 28.5-ft. trailers at 80,000 lbs. (control vehicle) and seven-axle tractor with three 28.5-ft. trailers at 105,500 lbs.:* This comparison (Comparison 3) uses WIM data from Oregon.

- **Table** 14 provides the details on the applicable axle weight and GVW limits in Oregon.
- *Five-axle tractor semitrailer with two 28.5-ft. trailers at 80,000 lb. (control vehicle) and seven-axle tractor with three 28.5-ft. trailers at 129,000 lb.:* This comparison (Comparison 4) uses the same seven-axle triple trailer configuration as in the previous comparison, even though the alternative 129,000-lb. configuration has nine axles. The seven-axle configuration is used because it currently operates in Nevada and Utah; the nine-axle configuration is not commonly used. The comparison uses WIM data from Nevada and Utah.
- **Table** 14 provides the details on the applicable axle weight and GVW limits in these States.

Table 14: Weight Limits for the Multiple-Trailer Truck Configurations included in the Compliance Assessment

	Weight Limits on Interstate (pounds)		**Weight Limits off Interstate** (pounds)	
State and Configuration	**Single Axle** [1]	**GVW**	**Single Axle** [1]	**GVW**
Comparison 3 (Oregon)				
Control Vehicle  2-S1-2 @ 80K lb. (2 x 28.5’)	20,000	Bridge formula up to 105,500, but must have permit above 80,000	20,000	Bridge formula up to 105,500, but must have permit above 80,000
Alternative Configuration  2-S1-2-2 @ 105K lb. (3 x 28.5’)	20,000	Bridge formula up to 105,500 (under annual permit)	20,000	Bridge formula up to 105,500 (under annual permit)
Comparison 4 (Nevada and Utah)				
Control Vehicle  2-S1-2 @ 80K lb. (2 x 28.5’)	20,000	80,000 [2]	20,000	80,000 [2]
Alternative Configuration  2-S1-2-2 @ 129K lb. (3 x 28.5’)	20,000	129,000	20,000	129,000

[1] This limit may be governed by the tire manufacturer’s rating.
[2] In Utah, this vehicle may operate between 80,000 and 112,000 lb. (depending on the bridge formula). Practically, however, the configuration would typically operate within 80,000 lb. to enable interstate moves.

Two comparisons are not included in the compliance assessment. Comparison of the five-axle tractor semitrailer (53 ft.) at 80,000 lbs. (control vehicle) with the same configuration at 88,000 lb. is not included because it is not possible to distinguish the subset of five-axle tractor semitrailers that would be subject to the higher weight limit. The comparison of the five-axle tractor with two 28.5-ft. trailers at 80,000 lbs. (control vehicle) with the alternative truck configuration with two 33-ft. trailers is not feasible because the alternative configuration is not currently in use in the United States.

At the selected WIM locations, the configurations being compared are isolated from the WIM dataset using axle-based vehicle classification algorithms. Then, cumulative probability distributions are used to analyze the loads for each axle group (i.e., single, tandem, tridem, as appropriate for each configuration) and the gross vehicle load. These distributions facilitate the compliance assessment using the following performance measures:[4]

- *Gross vehicle weight-compliant, proportion*: the fraction (or percentage) of the gross vehicle weight observations which is less than (or equal to) the legal (static) gross vehicle weight limit.
- *Gross vehicle overweight, severity*: the extent (in pounds) to which average measured gross vehicle weights for the observed subset of overweight trucks exceeds the legal (static) gross vehicle weight limit.
- *Single-axle weight-compliant, proportion*: the fraction (or percentage) of the single-axle weight observations which is less than (or equal to) the legal (static) single-axle weight limit.
- *Single-axle overweight, severity*: the extent (in pounds) to which average measured single-axle weights for the observed subset overweight single axles exceeds the legal (static) single-axle weight limit.
- *Tandem-axle weight-compliant, proportion*: the fraction (or percentage) of the tandem-axle weight observations which is less than (or equal to) the legal (static) tandem-axle weight limit.
- *Tandem-axle overweight, severity*: the extent (in pounds) to which average measured tandem-axle weights for the observed subset of overweight tandem axles exceeds the legal (static) tandem-axle weight limit.
- *Tridem-axle weight-compliant, proportion*: the fraction (or percentage) of the tridem-axle weight observations which is less than (or equal to) the legal (static) tridem-axle weight limit.
- *Tridem-axle overweight, severity*: the extent (in pounds) to which average measured tridem-axle weights for the observed subset of overweight tridem axles exceeds the legal (static) tridem-axle weight limit.

When assessing truck weight compliance using WIM data, it is important to note two issues that arise because of the nature of the WIM measurements. First, as stated earlier, WIM devices measure axle weights while trucks are in motion and are therefore subject to the dynamic interactions between the vehicle and the road. As such, an overweight observation by a WIM may not result in an overweight observation if the same axle (or truck) is weighed on a static scale. Because of this, the analysis differentiates between an overweight observation as recorded by a WIM and a violation or citation, which normally arises from a static weighing with reference to a legal (static) load limit. For the same reasons, a weight-compliant observation by a WIM cannot be unequivocally deemed to be in compliance with applicable weight laws. The

[4] These performance measures have been adapted from work by Hanscom (1998).

definitions of the performance measures used in the compliance assessment reflect these realities.

Second, because most WIM scales are not selective about the trucks they weigh (i.e., a WIM scale does not target a vehicle for weighing based on the likelihood that it is overweight), the proportion and severity of overweight observations is representative of all trucks passing over the scale during the observation period. In contrast, the proportion and severity of overweight observations at portable scales or even a static weigh scale could reflect targeting of trucks likely to be overweight. By extension, it is incorrect to assume that the proportion of weight-compliant vehicles observed at a WIM scale is the same as that observed at portable or static weigh scales.

Despite these inherent issues and the uncontrolled factors identified above, the WIM data allow the USDOT study team to conduct the necessary vehicle-specific compliance assessments to formulate pragmatic insights. In particular, by conducting the vehicle-specific compliance comparisons at the same WIM sites, the assessment limits the influence of some of these issues and factors. For example, while WIM calibration may vary in time and the local level of enforcement intensity may impact the axle weights observed at the WIM, these effects are expected to be largely independent of vehicle configuration.

The four comparisons provide the proportion of compliant GVW observations for four of the six alternative truck configurations introduced into the traffic stream through the applicable scenarios (i.e., Scenarios 2, 3, 5, and 6). This component of the analysis assumes that these proportions, which were observed at locations which facilitated direct comparisons of the control and alternative truck configurations, are applicable under base case and scenario traffic conditions. To extend these results to the scenarios and apply them to the VMT estimates for the control and alternative truck configurations in these scenarios, the analysis assumes that the compliant GVW proportions observed at the selected sites (i.e., specific points on the network) also apply across the network as a whole. In other words, this assumption considers the compliant proportion of GVW observations measured at a point to be the same as the weight-compliant proportion of VMT for the control and alternative truck configurations that would be observed over the network. Following these assumptions, for each of the four scenarios, the analysis calculates the total (combined) proportion of weight-compliant VMT for the control vehicle and alternative truck configuration for the base case and compares this to the total (combined) proportion of weight-compliant VMT of the same two configurations under the scenario traffic conditions. Thus, the scenario analysis reveals the system-wide impacts on enforcement effectiveness—as measured by compliance outcomes—that could result from the introduction of the alternative truck configurations into the traffic stream.

3.3 Results

This results section:

- Summarizes national-level truck weight enforcement program output trends and develops and examines pertinent relationships between certain outputs and program inputs.
- Compares the effectiveness of TSW enforcement programs for States that allow vehicles in excess of Federal truck weight limits (i.e., above-limit States) and States that do not allow vehicles in excess of Federal limits (i.e., at-limit States) using a State-level analysis.
- Analyzes enforcement effectiveness by assessing truck weight compliance outcomes (in terms of the proportion of weight-compliant observations and the severity of overweight observations) at a vehicle-specific level using WIM data at selected locations.
- Identifies statutes and regulations pertaining to Federal truck size and weight limits that would be impacted in the event of changes to these limits.

National-Level Output Trends and Relationships

This section summarizes national-level truck weight enforcement program outputs, including:

- Weighings by type (i.e., weighings at fixed, semi-portable, portable, and WIM scales);
- Citations by type (i.e., axle weight, GVW, and bridge formula);
- Number of load shifting and offloading vehicles; and
- Overweight permits issued by type (i.e., divisible, non-divisible, trip, and annual permits).

The Annual Certifications of Truck Size and Weight Enforcement database contains data reported by States for each of these output measures. A total of 50 States report data, including the 49 jurisdictions in the contiguous United States and Alaska. However, there are instances where certain data elements may be unavailable for specific States in a particular year. The following analysis first summarizes the output statistics for all the States that reported in each year from 2008 through 2012. Then, to facilitate a more reliable and detailed understanding of annual changes and trends, the analysis examines data from a subset of 44 States for which a complete set of data were available in each year.

In addition, the discussion develops three pertinent effectiveness relationships: the weighing cost efficiency (calculated as non-WIM weighings per personnel cost), the citation rate (calculated as citations per non-WIM weighing), and the relationship between citation rate and enforcement intensity (calculated as weighings per truck VMT). These relationships provide an output-based perspective of program effectiveness.

Nationwide Enforcement Program Outputs

Table 15 summarizes the nationwide annual outputs of State enforcement programs from 2008 through 2012 as reported in the Annual Certifications of Truck Size and Weight Enforcement database. Output data were unavailable for four States in 2008 and three States in 2012. On average, all States combined reported conducting a total of approximately 188 million weighings annually, of which over 60 percent were conducted by a WIM device. States issued an average of approximately 865,000 weight-related citations (GVW, axle, and bridge) annually during this time period, and approximately 73,000 size-related citations annually. An average of pproximately 324,000 vehicles were required each year to shift loads or off-load cargo as a result of a weighing that indicated a weight violation. Finally, States issued an average of about 4.8 million permits each year for oversize and overweight loads.

Table 15: Nationwide Enforcement Outputs for All Reporting States: 2008-2012

	Nationwide Enforcement Outputs by Year				
Output	**2008**	**2009**	**2010**	**2011**	**2012**
Total weighings (non-WIM plus WIM)	196,940,491	182,142,635	188,650,255	185,803,049	184,096,458
Total weight citations	1,023,109	883,216	896,864	765,760	757,379
Total size citations	88,375	80,802	74,901	60,997	58,836
Load-shifting & offloading vehicles	383,262	355,993	322,601	283,810	275,373
Total permits	5,189,507	4,523,348	4,887,963	4,987,733	4,287,088
# of States	46	50	50	50	47

In general, these output data (without normalizing for the different number of reporting States) indicate year-to-year decreases in the level of enforcement activity over this time period. Specifically, the number of reported total weighings (non-WIM and WIM weighings) was lower in 2012 than in 2008, and was at its lowest level in 2009. Similarly, the total number of weight and size citations dropped from 2008 to 2012, as did the number of vehicles required to shift loads or offload cargo and the number of permits issued for oversize and overweight loads. By comparison, trends in the level of resources dedicated to enforcement personnel over this same period peaked in 2010 before stabilizing at approximately 2010 values in 2011 and 2012. The impact of the national recession and the stress on state budgets is evident when viewing these trends.

Table 16 normalizes the weighings data for the 44 States which reported total (non-zero) weighings in each year from 2008 through 2012. This normalized data reduces potential bias in the annual changes and trends evident from the data resulting from differences in the number of States for which data were available in each year. The normalized analysis first examines weighings and citations and then considers permitting for oversize and overweight loads. Based on these values, the total reported number of weighings decreased from 2008 to 2012, from a maximum value of 196 million in 2008 to 180 million in 2012. The largest year-to-year decrease occurred from 2008 to 2009, when the total number of reported weighings declined to approximately 177 million from 196 million. Since 2009, the total number of reported weighings fluctuated between 177 million and 183 million annually.

Fixed platform weighings accounted for between 35 and 40 percent of the total number of weighings in each year, and nearly all (about 99 percent) of the non-WIM weighings in each year. The number of fixed platform weighings decreased by 22 percent from 2008 to 2009 before exhibiting more moderate fluctuations from 2009 to 2012. Portable weighings represented less than one percent of total non-WIM weighings in each year. Year-to-year, the number of portable weighings exhibited a pattern similar to the number of fixed platform weighings. Semi-portable weighings also accounted for less than 1 percent of total non-WIM weighings in each year. Unlike the trends observed for fixed platform and portable weighings, the number of weighings using semi-portable scales peaked in 2009 and has subsequently declined each year since then, with a 24 percent decrease between 2011 and 2012. WIM weighings accounted for between 60 and 65 percent of the total number of weighings in each year. The number of WIM weighings decreased by 10 percent from 2008 to 2009 and remained at approximately 2009 levels through 2012.

Table 16: Nationwide Number of Weighings for 44 Reporting States: 2008-2012

	Nationwide Number of Weighings by Year [1] *Percent Change of Weighings from Previous Year*				
Scale Type	**2008**	**2009**	**2010**	**2011**	**2012**
Fixed platform	79,171,055	64,664,598 *-22%*	69,141,343 *6%*	64,354,898 *-7%*	71,493,875 *10%*
Portable	582,626	512,342 *-14%*	554,788 *8%*	521,894 *-6%*	554,514 *6%*
Semi-portable	353,984	373,716 *5%*	350,998 *-6%*	328,544 *-7%*	264,699 *-24%*
Total (Non-WIM)	**80,107,665**	**65,550,656** *-22%*	**70,047,129** *6%*	**65,205,336** *-7%*	**72,313,088** *10%*
WIM	115,913,985	111,897,092 *-4%*	113,094,061 *1%*	113,493,183 *0%*	107,793,559 *-5%*
Total	**196,021,650**	**177,447,748** *-10%*	**183,141,190** *3%*	**178,698,519** *-2%*	**180,106,647** *1%*

[1] The statistics shown in the table are summed for the 44 States that reported total (non-zero) values for each year 2008 through 2012.

Table 17 shows the normalized number of weight citations issued from 2008 through 2012 in the 44 States. Over this time, the total reported number of weight citations decreased from 2008 to 2012, from a maximum value of approximately 1 million in 2008 to about 750,000 in 2012. Year-to-year decreases were particularly evident from 2008 to 2009 and from 2010 to 2011. More specifically, of the total number of weight citations, the proportional distribution of the type of citations in each year remained relatively consistent. Citations for excessive GVW represented nearly 60 percent of the total number of weight citations in each of the 5 years, excessive axle weight citations represented nearly 25 percent of total weight citations, and citations for weights exceeding the bridge formula represented nearly 20 percent of total weight-related citations.

Table 17 also summarizes annual statistics on the number of oversize citations and the number of vehicles required to shift a load or offload cargo as a result of the detection of a weight violation. The number of oversize citations decreased in each year, with the largest decrease occurring from 2010 to 2011. Proportionally, size-related citations consistently represented about 8 percent of the total number of citations (size and weight) issued. Additionally, over the 5 year period, the number of times a vehicle was required to shift a load as a result of a weight violation decreased steadily, while the number of times a vehicle was required to offload cargo remained relatively constant. Load shifting represented more than 80 percent of the total number of load change requirements (shifting plus offloading) in each of the five years.

Table 17: Nationwide Number of Citations for 44 Reporting States: 2008 - 2012

	Nationwide Number of Citations by Year [1] *Percent Change of Violations from Previous Year*				
Citation Type	**2008**	**2009**	**2010**	**2011**	**2012**
Overweight GVW	586,921	500,572	517,621	427,699	447,705
		-17%	*3%*	*-21%*	*4%*
Overweight Axle	244,797	214,872	210,320	170,128	170,473
		-14%	*-2%*	*-24%*	*0%*
Bridge Formula	185,695	151,502	145,790	150,794	135,743
		-23%	*-4%*	*3%*	*-11%*
Total Weight	**1,017,413**	**866,946**	**873,731**	**748,621**	**753,921**
		-17%	***1%***	***-17%***	***1%***
Oversize	88,369	78,814	73,162	59,913	58,797
		-12%	*-8%*	*-22%*	*-2%*
Load shifting vehicles[2]	329,844	300,195	266,846	232,952	223,656
		-10%	*-12%*	*-15%*	*-4%*
Offloading vehicles[2]	52,572	49,830	50,219	45,937	51,344
		-6%	*1%*	*-9%*	*11%*

[1] The statistics shown in the table are summed for the 44 States that reported total (non-zero) values for

In addition to weighings and citations, the output of an enforcement program includes permits issued for oversize and overweight loads. Motor carriers transporting non-divisible, oversize/overweight (OS/OW) freight must first obtain appropriate permits, routing, and approvals from State authorities. Each State is recognized as independent in administering OS/OW permit processes according to its own statutes and regulations. OS/OW permits are the most frequently issued commercial vehicle credential. Some motor carriers apply for multiple OS/OW permits on a daily basis from multiple jurisdictions.

The current TSW regulations are a blend of Federal and State regulations. Federal law controls maximum gross vehicle weights and axle loads on the Interstate System. Current Federal limits are 80,000 lbs. GVW, 20,000 lbs. on a single axle, and 34,000 lbs. on a tandem axle group. The Federal Bridge Formula controls the stresses placed on bridges. When the Federal limits were imposed in 1956, 33 States had laws in effect that allowed higher weights on some highways. Those higher weight limits were "grandfathered" and States were permitted to allow those higher weights on their Interstate highways. Since 1956 many State-specific exemptions, which allow vehicles heavier than Federal weight limits on the Interstate System, have been enacted. These often pertain only to individual commodities or specific highways. All States may issue permits allowing vehicles carrying non-divisible loads to operate above Federal weight limits on the Interstate system, and a majority also has grandfathered authority to issue divisible load permits.

Single trip OS/OW permits are valid only for a single trip. Multiple trip OS/OW permits may be issued for a number of trips or set a period of time (often 1 year, hence the term “annual permit”) as each State may determine. Routing for either single trip or multiple trip permits can be either for a specific route or for a network system (AASHTO, 2001).

As per 23 CFR 658.5, a non-divisible load is defined as one that can exceed legal size and weight limits and cannot be reasonably divided, broken down, or dismantled to conform to legal limitations. Certain machinery and electric transformers are good examples of non-divisible loads. A divisible load is defined as one that can be divided, broken down, or dismantled to conform to legal limitations.

Often, certain commodities may be transported under permit at certain times. For example, in Louisiana, sugar cane transported during the harvest season may be hauled by trucks with gross weights up to 100,000 pounds. Also, under Section 1511 of the MAP-21 legislation (Public Law 112-141), special permits for divisible loads are allowed during periods of national emergency if declared by the President under the Robert T. Stafford Disaster Relief and Emergency Assistance Act. Sixteen States have grandfather authority for moving divisible loads above the legal limit on the Interstate System. All States have authority to permit the movement of non-divisible loads on the Interstate System and to permit divisible and non-divisible loads on non-Interstate State highways.

A limited number of States have developed information systems that allow roadside enforcement personnel to electronically validate an OS/OW permit in real-time. Anecdotal information suggests that in States that have deployed automated permitting systems, compliance rates for obtaining OS/OW permits by motor carriers have increased significantly. Proper permitting and routing enhances safety, preserves infrastructure, and can potentially limit the impact of OS/OW movements on the mobility of other vehicles (I-95 Corridor Coalition and FHWA, 2008).

Table 18 shows the normalized number of permits (by permit type) issued from 2008 through 2012 in the 44 States. Over this time, the total reported number of permits increased from a maximum of 4.1 million in 2008 to about 4.2 million in 2012. An 11 percent year-to-year decrease occurred between 2008 and 2009, followed by steady increases from 2010 through 2012. The proportional distribution of total **permits** issued in each year remained relatively consistent. Non-divisible trip permits accounted for between 80 and 83 percent of total permits in each year, non-divisible annual permits accounted for about 6 percent, divisible trip permits accounted for 6 percent, and divisible annual permits accounted for between 9 and 12 percent.

Table 18: Nationwide Number of Permits Issued for 44 Reporting States: 2008-2012

	Nationwide Number of Permits by Year [1] *Percent Change of Permits from Previous Year*				
Permit Type	**2008**	**2009**	**2010**	**2011**	**2012**
Non-divisible trip	3,411,636	2,987,590 *-14%*	3,222,452 *7%*	3,446,444 *6%*	3,490,566 *1%*
Non-divisible annual	263,082	244,736 *-7%*	242,776 *-1%*	260,290 *7%*	272,939 *5%*
Divisible trip	65,401	89,703 *27%*	79,236 *-13%*	97,389 *19%*	88,918 *-10%*

	Nationwide Number of Permits by Year [1] *Percent Change of Permits from Previous Year*				
Permit Type	**2008**	**2009**	**2010**	**2011**	**2012**
Divisible annual	358,731	359,201	503,871	369,897	383,333
		0%	*29%*	*-36%*	*4%*
Total	**4,098,850**	**3,681,230**	**4,048,335**	**4,174,020**	**4,235,756**
		-11%	***9%***	***3%***	***1%***

[1] The statistics shown in the table are summed for the 44 States that reported total (non-zero) values for each year from 2008 to 2012.

Pertinent Effectiveness Relationships

The results of the normalized analysis of enforcement outputs can be used to develop three pertinent output-based relationships that illustrate enforcement effectiveness: weighing cost-efficiency, citation rate, and citation rate as a function of enforcement intensity.

Weighing cost efficiency is a measure of effectiveness that relates program inputs (in terms of personnel costs) to program outputs (in terms of non-WIM weighings). Essentially, weighing cost efficiency indicates the extent of weighing activity completed given the level of financial resources attributed to enforcement personnel.

Table 19 shows the weighing cost efficiency in each year from 2008 to 2012, inclusive. A subset of 35 States which reported both total non-WIM weighings and total personnel costs in each of the 5 years comprise the data reported in the table. Between 2008 and 2010, weighing cost efficiency decreased from 173 to 125 weighings per $1,000 before stabilizing at about this level in 2011 and 2012. Put another way, each non-WIM weighing cost approximately $8 in 2012 compared to less than $6 in 2008 (in 2011 USD).

Table 19: Nationwide Weighing Cost-Efficiency for 35 Reporting States: 2008-2012

	Nationwide Weighing Cost-efficiency by Year [1] *Percent Change from Previous Year*				
	2008	**2009**	**2010**	**2011**	**2012**
Total non-WIM weighings	65,674,380	55,510,405	56,431,193	53,517,386	55,609,799
		-18%	*2%*	*-5%*	*4%*
Total personnel costs (thousand 2011 USD)	$378,727	$393,267	$451,025	$447,520	$448,117
		4%	*13%*	*-1%*	*0%*
Weighing cost-efficiency (weighings / thousand 2011 USD)	173	141	125	120	124
		-23%	*-13%*	*-5%*	*4%*

[1] The statistics shown in the table are summed for the 35 States that reported total (non-zero) values for each year from 2008 through 2012.

A citation rate is a measure of effectiveness that relates two program outputs: weighings and citations. Essentially, a citation rate indicates the proportion of weighings (other than weighings by a WIM) that translated into weight citations. It is determined by dividing the total number of weight citations (axle, gross, and Bridge Formula) by the total number of non-WIM weighings. WIM weighings are excluded from this calculation because they are not currently used to issue a citation directly.

Table 20 shows the citation rates in each year from 2008 through 2012. The citation rate in 2008 is 0.013 citations per non-WIM weighing. In other words, about 1.3 percent of vehicles weighed were cited for a weight violation. This rate decreases steadily through 2012 to a value of 0.010 citations per non-WIM weighing.

Table 20: Nationwide Citation Statistics for 44 Reporting States: 2008-2012

	Nationwide Citation Statistics by Year [1] *Percent Change from Previous Year*				
	2008	**2009**	**2010**	**2011**	**2012**
Total weighings (non-WIM)	80,107,665	65,550,656 *-22%*	70,047,129 *6%*	65,205,336 *-7%*	72,313,088 *10%*
Total weight citations	1,017,413	866,946 *-17%*	873,731 *1%*	748,621 *-17%*	753,921 *1%*
Citation rate [citations / weighings]	0.013	0.013 *4%* [2]	0.012 *-6%*	0.011 *-9%*	0.010 *-10%*

[1] The statistics shown in the table are summed for the 44 States that reported total (non-zero) values for each year from 2008 to 2012, inclusive.
[2] There is a four percent increase in the citation rate from 2008 to 2009, even though this increase is not apparent from the rounded citation rates.

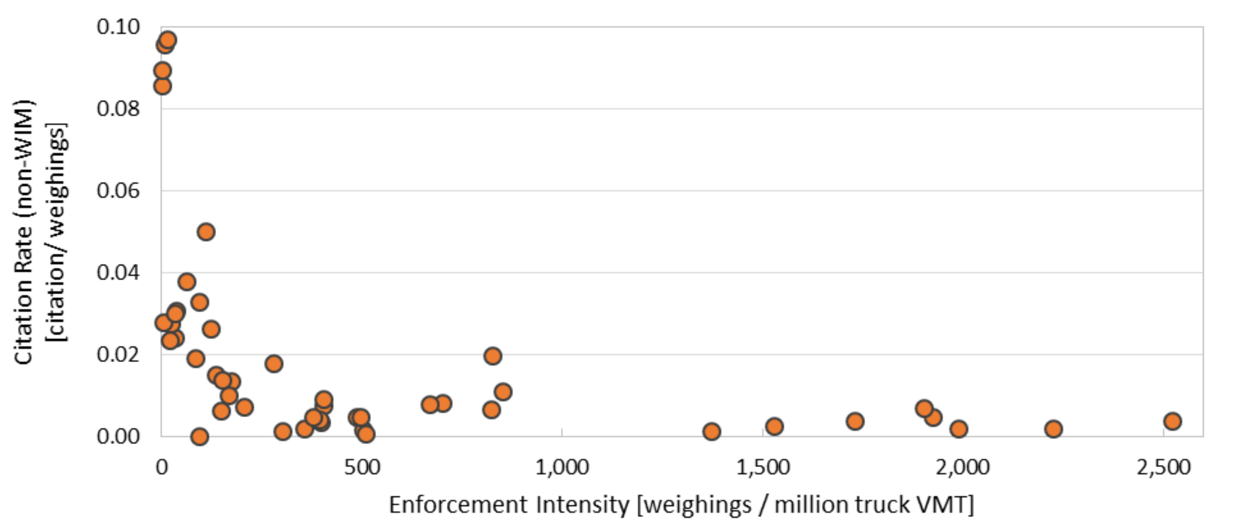
A citation rate is one indication of enforcement program effectiveness, but interpretation of this rate is somewhat complex. Ultimately, if the enforcement program met its compliance objectives, the citation rate would in theory be zero. This would arise if all weighings indicated weight compliance and could signal an effective enforcement program. However, the likelihood of observing a weight violation that could result in a citation depends on the enforcement method (e.g., fixed, portable), the intensity or frequency of that enforcement, and ultimately the predictability of the weighings being conducted. For example, one might expect a relatively low citation rate if weighings are conducted in a highly predictable way, enabling weight violators to avoid detection. Conversely, a relatively high citation rate could result from a weight enforcement program that is unpredictable in space and time or one which employs targeting strategies to detect violators (or both). Thus, an enforcement program that relies on relatively unpredictable and potentially targeted portable weighings rather than fixed scale weighings could see a relatively high citation rate—an indication of an effective program. Presumably, consistent application of such an unpredictable or targeted program would eventually lead to lower citation rates if the probability of detection and penalty severity was sufficiently high.

Examining the relationship between citation rate and enforcement intensity provides a third perspective on enforcement effectiveness by revealing the impact of the intensity and method of enforcement on citation rates. Factors associated with the industries in a particular region, the commodities hauled and truck configurations used to carry these loads, and temporal considerations may also impact citation rates, but are not examined here.

The data available from the Annual Certifications of Truck Size and Weight Enforcement database enable systematic analysis of the relationship between citation rate and the intensity of weight enforcement in a State, but cannot be used to disaggregate citations by enforcement method (i.e., fixed, portable), industries or commodities, gross truck and axle weight, truck configurations, or temporal variations. As with the national-level analysis, the citation rate for each State is determined by dividing the number of weight citations by the total number of non-WIM weighings. To normalize the number of weighings in each State, enforcement intensity is calculated as the total weighings divided by the total truck miles traveled in each State.

Figure 9 shows the relationship between citation rate and enforcement intensity, where each point represents one State. Essentially, this relationship can be interpreted to suggest that at some point, increases in enforcement intensity (i.e., more weighings per truck VMT) cause no further decrease in the citation rate. In other words, when measuring effectiveness in terms of citation rates, increasing the intensity of enforcement beyond a certain point—approximately 500 weighings per million truck VMT based on the data shown in **Figure 9**—does not further decrease the citation rate. Presumably, there is a minimum citation rate that can be achieved through on-road enforcement (i.e., the curve approaches some minimum citation rate greater than zero), suggesting that no matter how intense the enforcement, there will always be some inadvertent or intentional violators. The available data suggest that this minimum citation rate may be approximately 0.005 citations per non-WIM weighing (or 0.5 percent).

Figure 9: Citation Rate as a Function of Enforcement Intensity: 2011



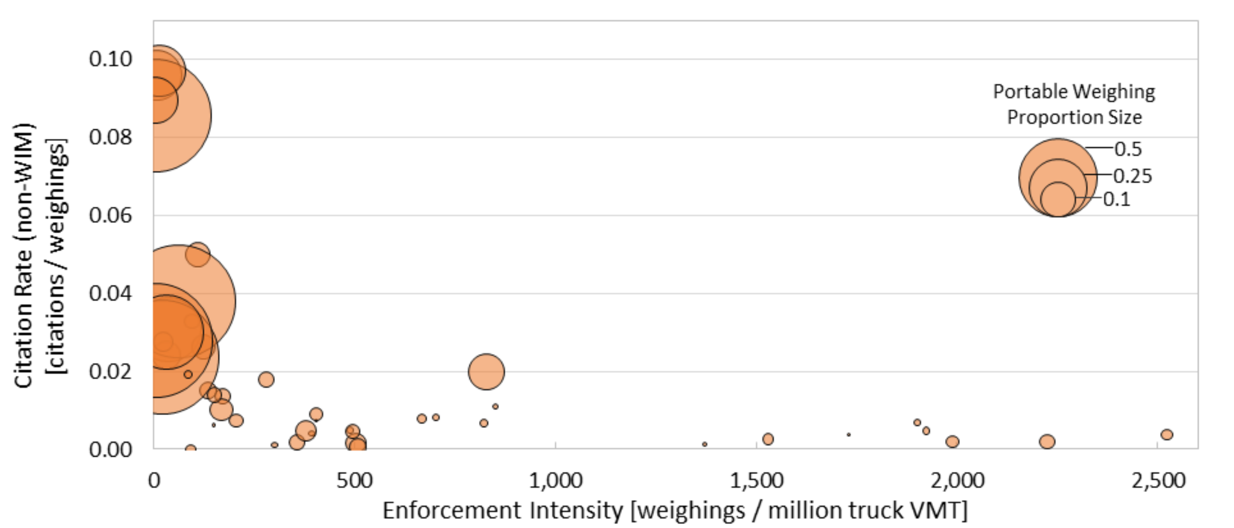
Notes: The figure excludes three States because the citation rates for these States exceed the scale of the figure; however, these States were included in the analysis. One State had a citation rate of 0.15 and an enforcement intensity of 132, another State had a citation rate of 0.19 and an enforcement intensity of 9, and the last State had a citation rate of 0.38 and an enforcement intensity of 2.

The foregoing interpretation, however, assumes that all States adopt similar enforcement methods (i.e., fixed, portable) and similar levels of enforcement targeting. Consider the portion of the curve where a relatively high citation rate is obtained with a relatively low enforcement intensity. One might conclude that this portion of the curve represents States that have a relatively ineffective truck weight enforcement program. The rationale for this conclusion is that a State does not enforce truck weights intensely enough (i.e., low enforcement intensity) and could improve enforcement effectiveness by increasing enforcement intensity and lowering the citation rate.

Conversely, one might also conclude that this portion of the curve represents States that have achieved a relatively effective enforcement program through less predictable (more random) or more targeted enforcement strategies that reduce the need for frequent weighings. The rationale for this conclusion is that a State that weighs vehicles less predictably or efficiently targets its limited enforcement resources towards times, places, industries, or carriers expected to be likely weight violators may observe a high citation rate with a relatively low enforcement intensity. Depending on the degree of unpredictability or enforcement targeting, this elevated citation rate may be a truer reflection of the actual magnitude of overweight trucking that more predictable and less flexible methods of enforcement do not detect, or, conversely, it may actually exaggerate the extent of overweight trucking. The effect however, may be temporary, as potential violators may eventually be less likely to violate if the perceived probability of detection is high and the consequences for operating overweight are sufficiently severe.

Figure 10 supports this latter interpretation of the relationship by sizing each point on the curve according to the relative emphasis that each State places on portable and semi-portable weighings compared to fixed weighings. The figure shows that those States that conduct a higher proportion of portable and semi-portable weighings generally have lower overall enforcement intensity and a higher citation rate. Further, when examining changes in citation rates for the nine States with a relatively high proportion of portable and semi-portable weighings (greater than 20 percent), there is some evidence that the citation rates appear to rise as the proportion of portable and semi-portable weighings increases, reach a maximum value, and then decline. While this effect cannot be systematically demonstrated, it does lend some support to the potentially temporary nature of the elevated citation rates being observed.

Figure 10: Citation Rate as a Function of Enforcement Intensity and Weighing Method: 2011



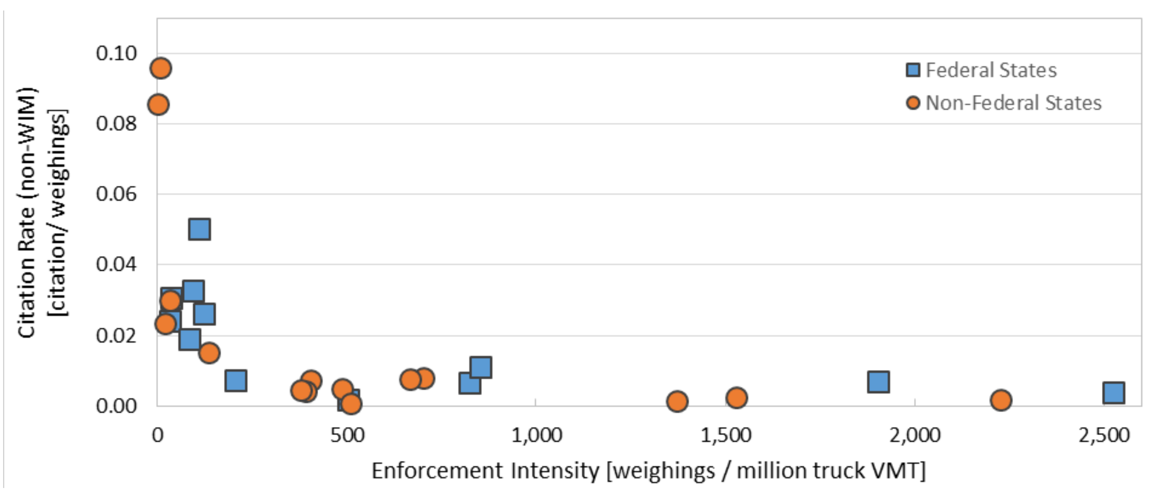
Notes: Each point in the figure represents one State. The size of each point reflects the proportion of total non-WIM weighings conducted by portable and semi-portable scales. The figure excludes three States because the citation rates for these States exceed the scale of the figure; however, these States were included in the analysis. One State had a citation rate of 0.15, an enforcement intensity of 132, and a 0.17 proportion of portable scale weighings. Another State had a citation rate of 0.19, an enforcement intensity of 9, and a 0.22 proportion of portable scale weighings. The last State had a citation rate of 0.38, an enforcement intensity of 2, and a 0.51 proportion of portable scale weighings.

State-Level Comparative Analysis

Building on the foregoing analysis of the relationship between citation rate and enforcement intensity, **Figure 11** depicts this relationship for only the 29 comparison States (see **Table 3**), identifying each State (or data point) as either an at-limit or above-limit. The figure reveals the same general relationship as in **Figure 9** for both the at-limit and above-limit State groups. Specifically, both at-limit and above-limit States exhibit a range of enforcement intensity, where those States with a low enforcement intensity (less than about 500 weighings per million truck VMT) have a relatively high citation rate compared to States with a higher enforcement intensity (more than about 500 weighings per million truck VMT). Further, when plotting this relationship by enforcement method (**Figure 12**), it is evident that those States that place a higher emphasis on portable and semi-portable weighings rather than fixed weighings—whether at-limit or above-limit—have a lower enforcement intensity and a higher citation rate.

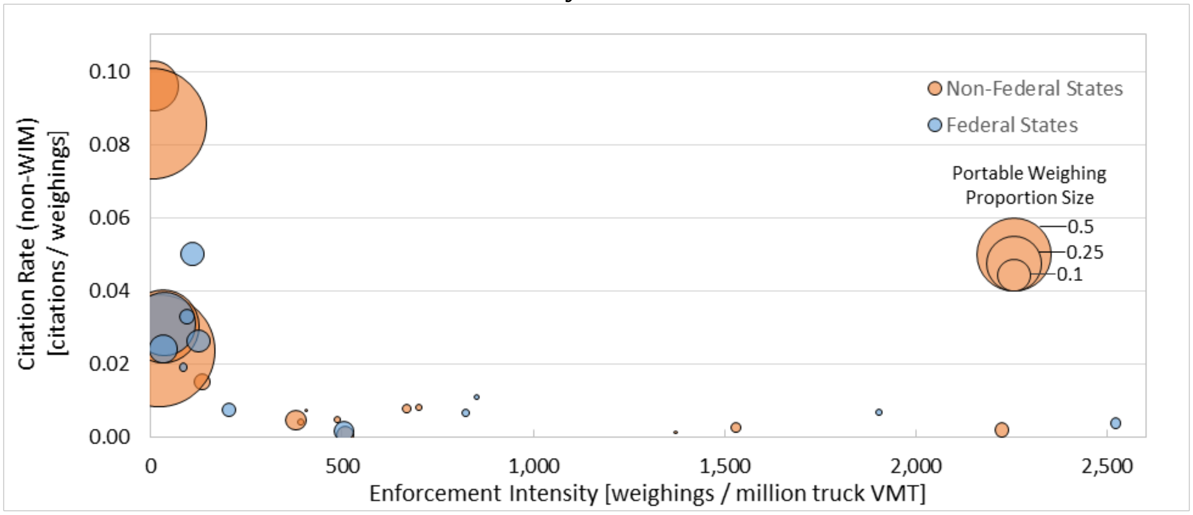
Therefore, based on this comparison, the interpretation of the relationship between citation rate and enforcement intensity provided in the foregoing section applies equally to at-limit and above-limit States. Put another way, the comparison of at-limit and above-limit States does not reveal any difference in enforcement program effectiveness when measured in terms of citation rate and enforcement intensity. Rather, effectiveness as measured by this relationship appears more sensitive to the enforcement method (i.e., fixed or portable weighings) used in the State.

Figure 11: Citation Rate as a Function of Enforcement Intensity for At-limit and Above-limit States: 2011



Notes: "Federal States" refers to States with maximum weight limits consistent with the 80,000 lb. Federal maximum GVW; these are also referred to as "at-limit States." "Non-Federal States" refers to States with maximum legal weight limits that exceed the Federal limits, also referred to as "above-limit States." The figure excludes two States (one at-limit and one above-limit) because the citation rates for these States exceed the scale of the figure; however, these States were included in the analysis. The at-limit State had a citation rate of 0.19 and an enforcement intensity of 9; the above-limit State had a citation rate of 0.38 and an enforcement intensity of 2.

Figure 12: Citation Rate as a Function of Enforcement Intensity for At-limit and Above-limit States by Enforcement Method: 2011



Notes: "Federal States" refers to States with maximum weight limits consistent with the 80,000 lb. Federal maximum GVW; these are also referred to as "at-limit States." "Non-Federal States" refers to States with maximum legal weight limits that exceed the Federal limits, also referred to as "above-limit States." The figure excludes two States (one at-limit and one above-limit) because the citation rates for these States exceed the scale of the figure; however, these States were included in the analysis. The at-limit State had a citation rate of 0.19, an enforcement intensity of 9, and a 0.2 proportion of portable scale weighings. The above-limit State had a citation rate of 0.38, an enforcement intensity of 2, and a 0.5 proportion of portable scale weighings.

Assessment of Compliance Outcomes for the Alternative Truck Configurations

This compliance assessment comprises an analysis of axle and gross vehicle load distributions for specific vehicle configurations at the selected WIM sites and compares these with the static weight limits in effect for these configurations at these sites. The comparisons use the performance measures listed and defined as part of the description of the compliance assessment methodology.

The templates shown in **Figure 13** to **Figure 22** (one template for each truck configuration) provide the results of the compliance assessments for the four vehicle-specific comparisons. Each template:

- Identifies the configuration, State(s), and analysis year;
- Provides information about the citation rate and enforcement intensity in the State(s), which is identified by the orange dot in the figure;
- Shows the cumulative probability distributions for each axle group (i.e., single, tandem, tridem), if relevant for the configuration, with accompanying statistics about the number of observations, mean, static weight limit, proportion of weight-compliant observations, severity of overweight observations, and static limit allowance (based on the accuracy of WIM devices); and

- Shows the cumulative probability distributions for the gross vehicle weight, with accompanying statistics about the number of observations, mean, static weight limit, proportion of weight-compliant observations, severity of overweight observations, and static limit allowance (based on the accuracy of WIM devices).

Figure 13: Performance Measures for the Comparison 1 Control Vehicle

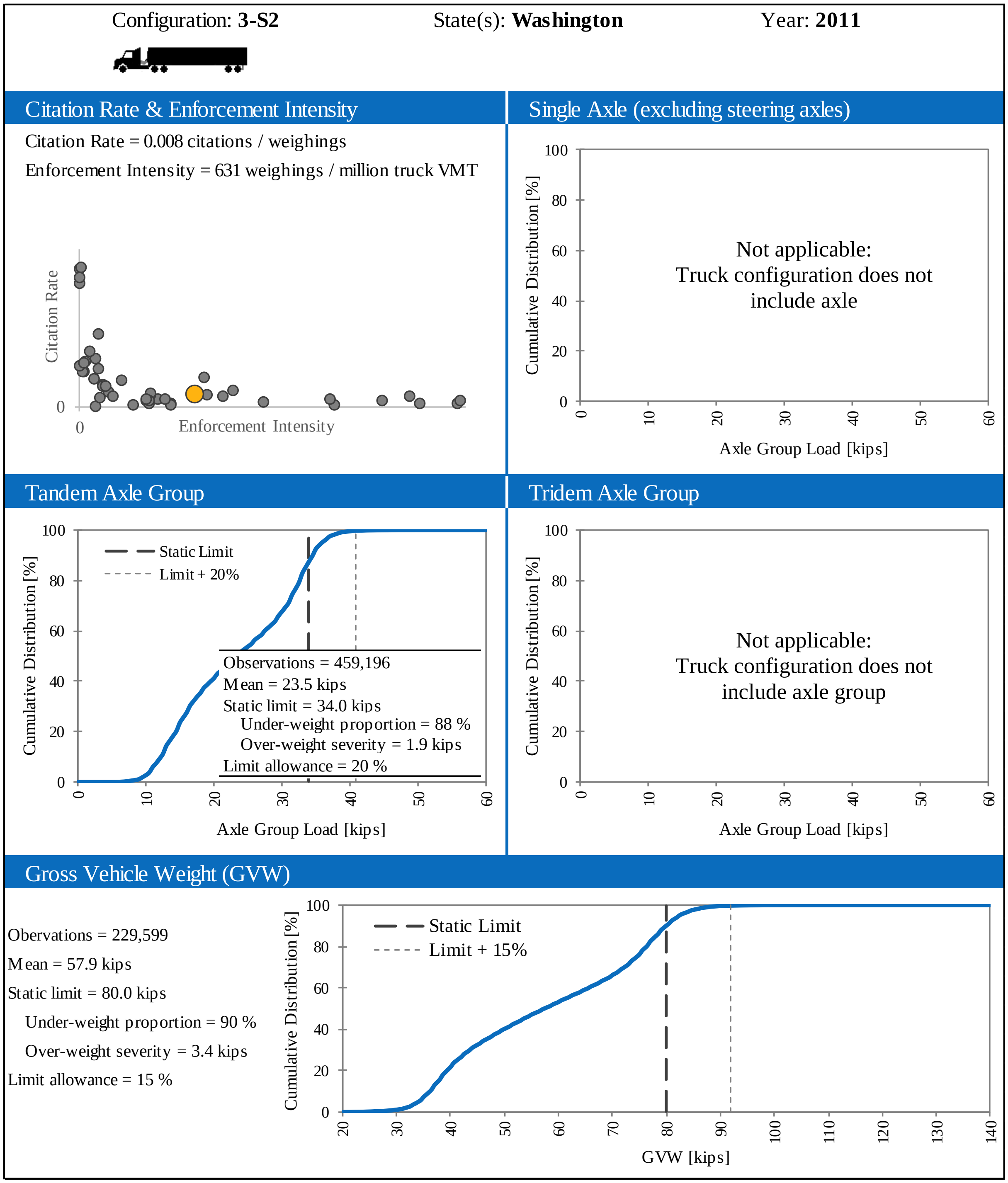


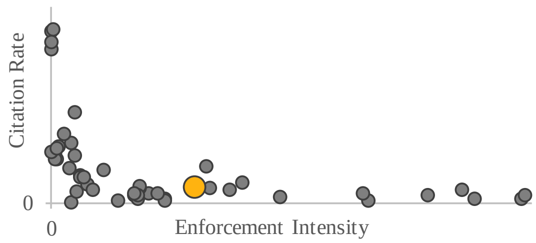
Figure 14: Performance Measures for the Comparison 1 Alternative Configuration

Configuration: **3-S3** State(s): **Washington** Year: **2011**

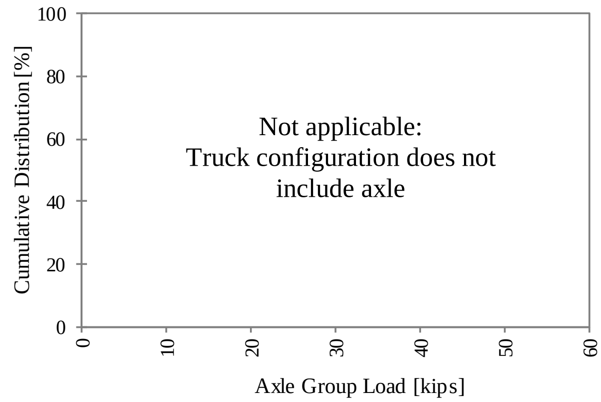
Citation Rate & Enforcement Intensity

Citation Rate = 0.008 citations / weighings

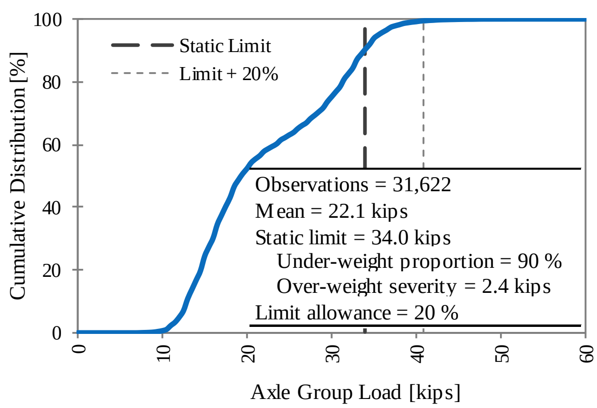
Enforcement Intensity = 631 weighings / million truck VMT



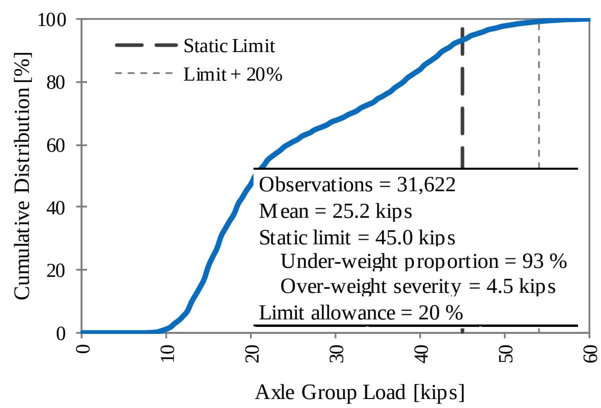
Single Axle (excluding steering axles)



Tandem Axle Group



Tridem Axle Group



Gross Vehicle Weight (GVW)

Obervations = 31,622

Mean = 58.4 kips

Static limit = 92.0 kips

Under-weight proportion = 95 %

Over-weight severity = 6.0 kips

Limit allowance = 15 %

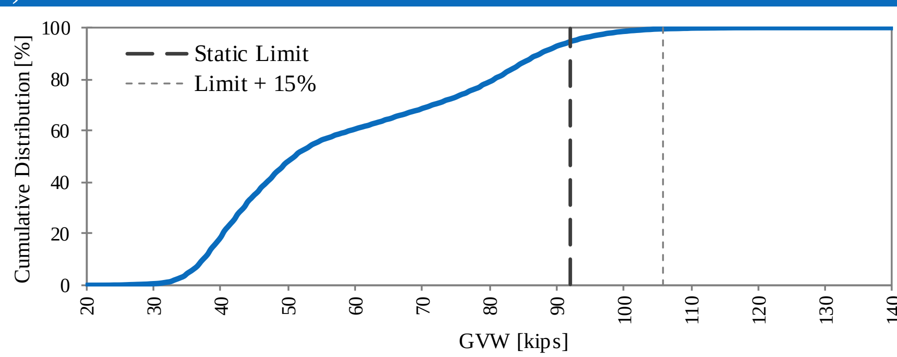


Figure 15: Performance Measures for the Comparison 2a Control Vehicle

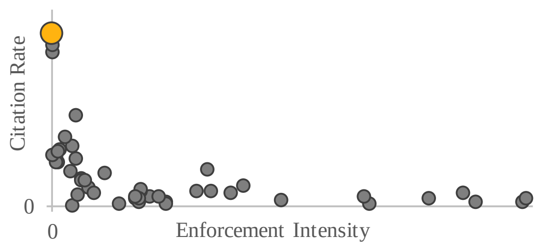
Configuration: **3-S2** State(s): **Maine** Year: **2011**

Functional Class: **On-Interstate**

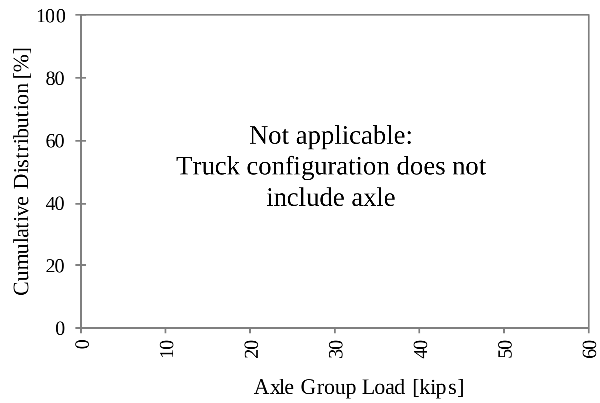
Citation Rate & Enforcement Intensity

Citation Rate = 0.096 citations / weighings

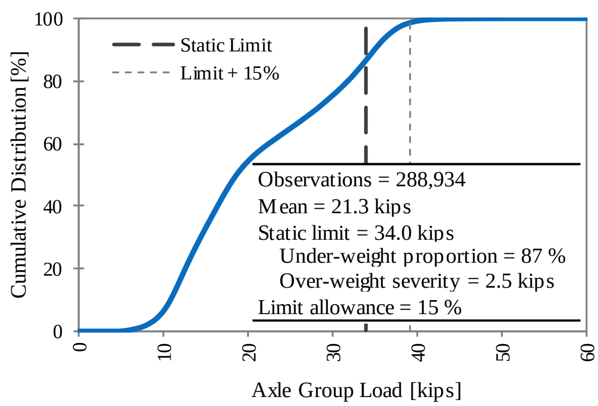
Enforcement Intensity = 7 weighings / million truck VMT



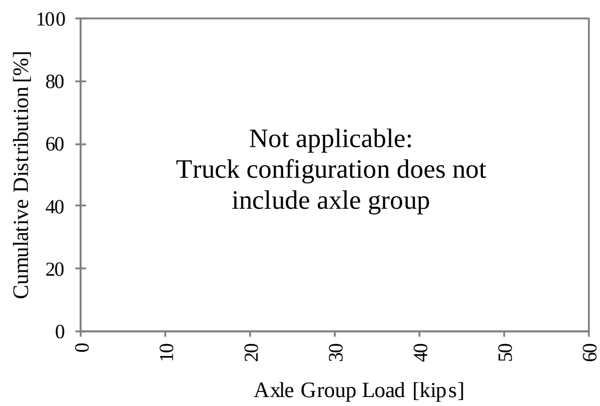
Single Axle (excluding steering axles)



Tandem Axle Group



Tridem Axle Group



Gross Vehicle Weight (GVW)

Obervations = 144,467

Mean = 54.0 kips

Static limit = 80.0 kips

Under-weight proportion = 87 %

Over-weight severity = 4.6 kips

Limit allowance = 10%

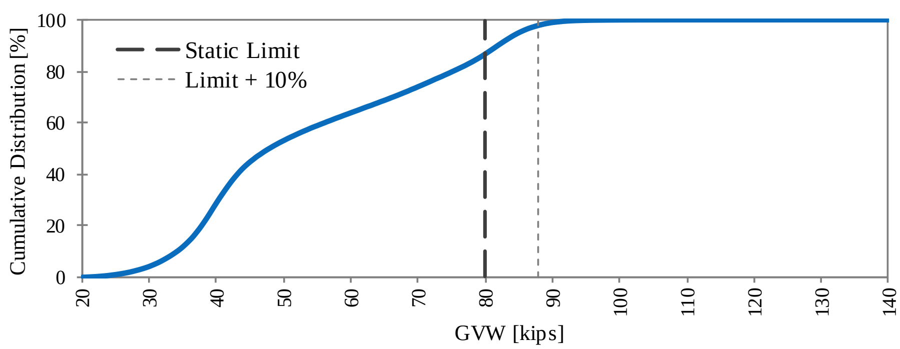


Figure 16: Performance Measures for the Comparison 2a Alternative Configuration

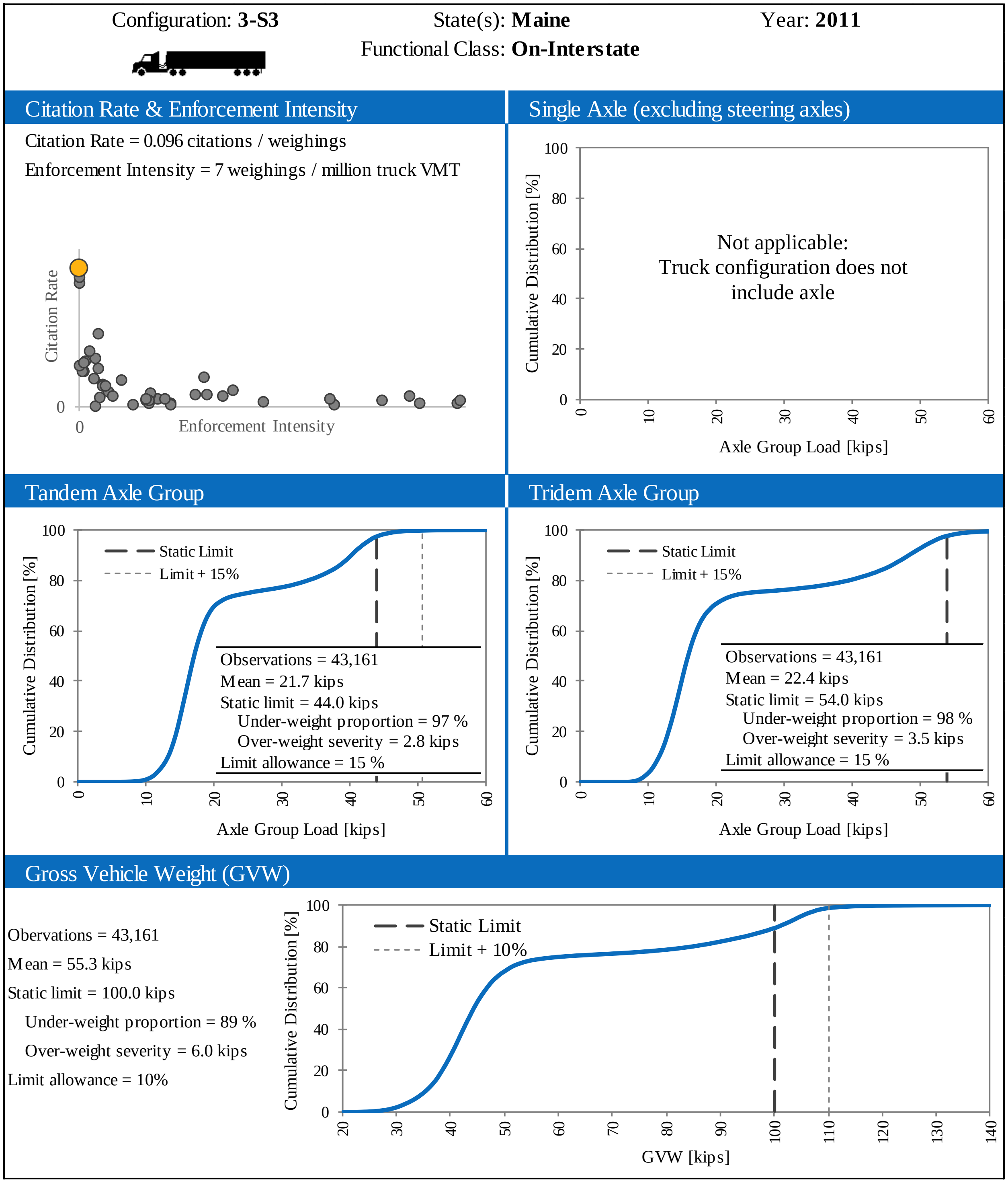


Figure 17: Performance Measures for the Comparison 2b Control Vehicle

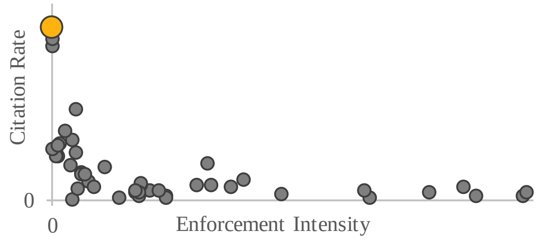
Configuration: **3-S2** State(s): **Maine** Year: **2011**

Functional Class: **Off-Interstate**

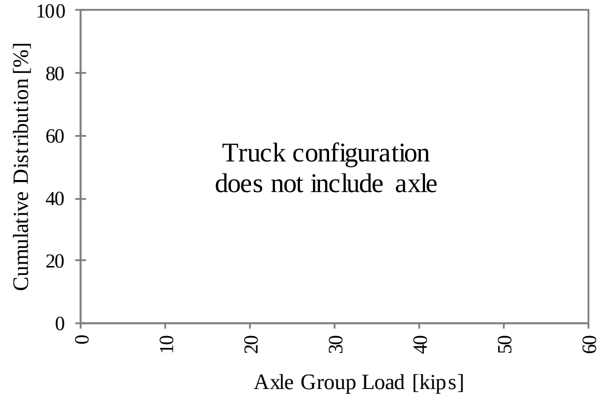
Citation Rate & Enforcement Intensity

Citation Rate = 0.096 citations / weighings

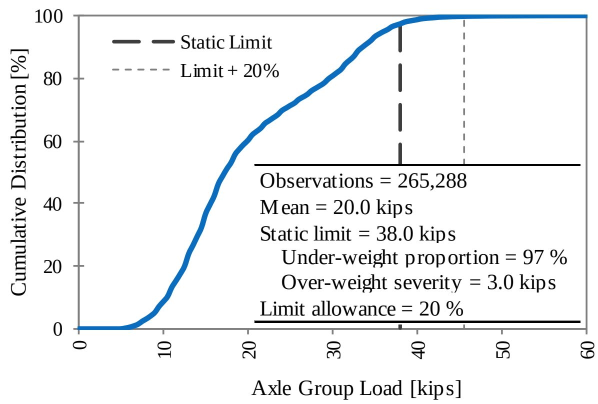
Enforcement Intensity = 7 weighings / million truck VMT



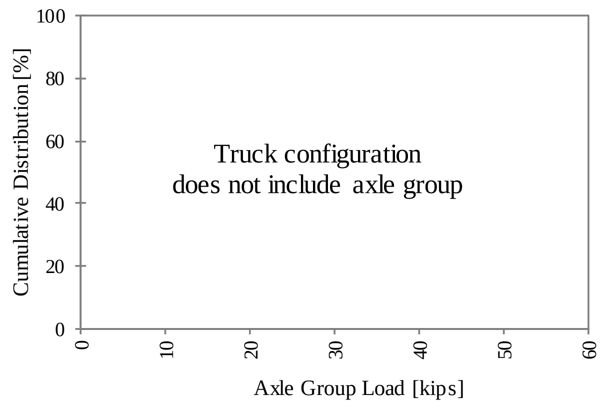
Single Axle (excluding steering axles)



Tandem Axle Group



Tridem Axle Group



Gross Vehicle Weight (GVW)

Obervations = 132,644

Mean = 49.5 kips

Static limit = 80.0 kips

Under-weight proportion = 93 %

Over-weight severity = 6.4 kips

Limit allowance = 15 %

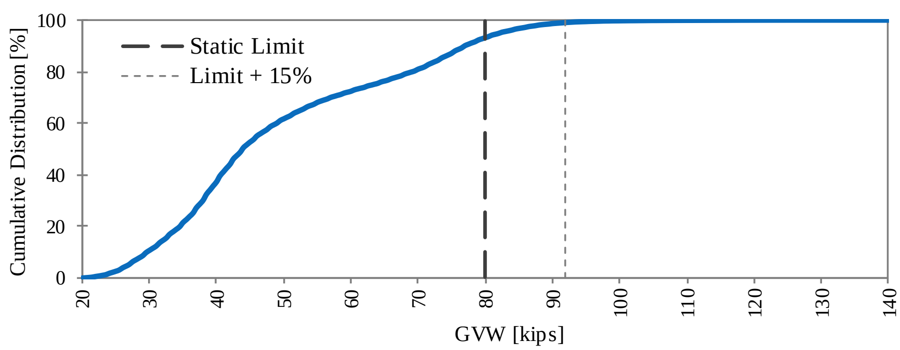


Figure 18: Performance Measures for the Comparison 2b Alternative Configuration

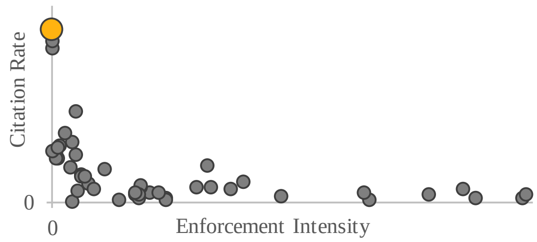
Configuration: **3-S3** | State(s): **Maine** | Year: **2011**

Functional Class: **Off-Interstate**

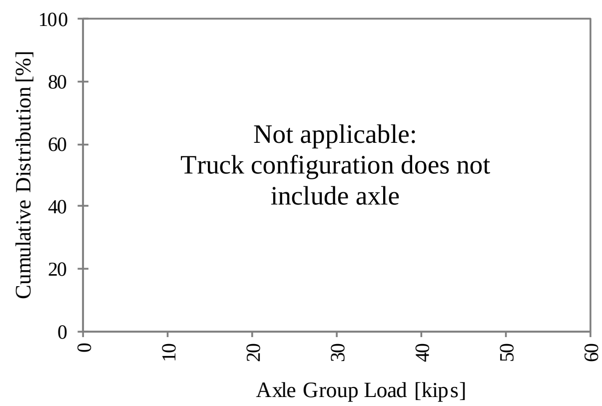
Citation Rate & Enforcement Intensity

Citation Rate = 0.096 citations / weighings

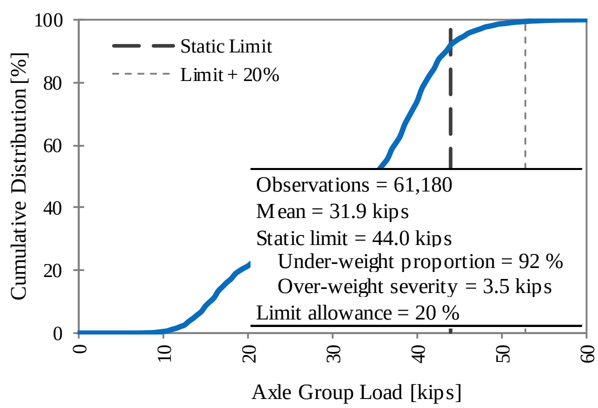
Enforcement Intensity = 7 weighings / million truck VMT



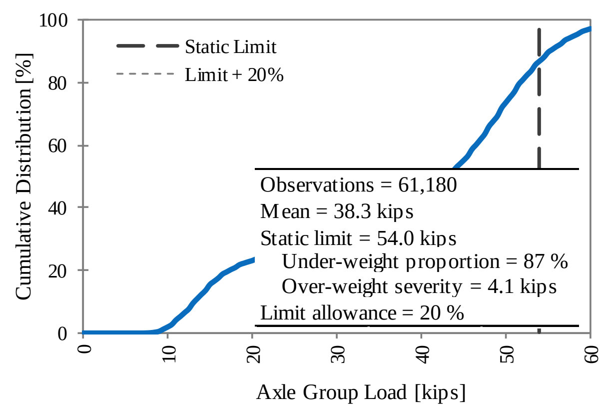
Single Axle (excluding steering axles)



Tandem Axle Group



Tridem Axle Group



Gross Vehicle Weight (GVW)

Obervations = 61,180

Mean = 80.1 kips

Static limit = 100.0 kips

Under-weight proportion = 73 %

Over-weight severity = 8.0 kips

Limit allowance = 15 %

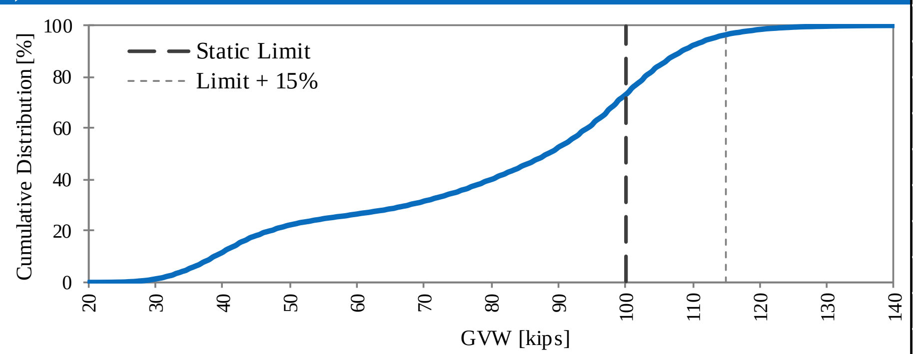


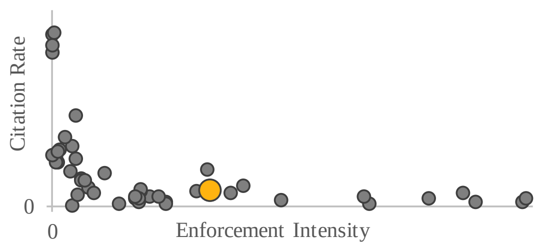
Figure 19: Performance Measures for the Comparison 3 Control Vehicle

Configuration: **2-S1-2** State(s): **Oregon** Year: **2011**

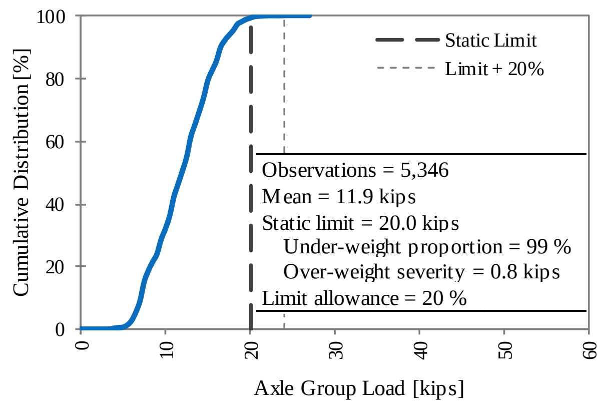
Citation Rate & Enforcement Intensity

Citation Rate = 0.008 citations / weighings

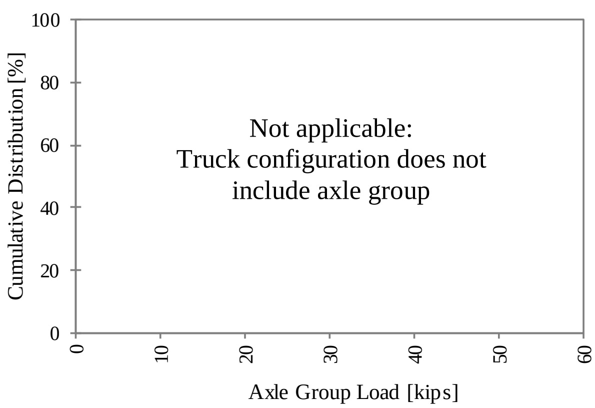
Enforcement Intensity = 699 weighings / million truck VMT



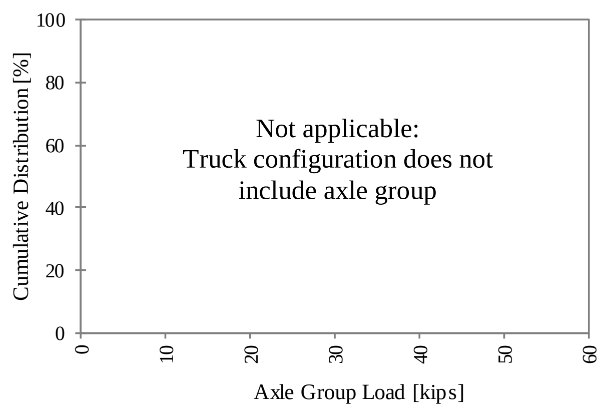
Single Axle (excluding steering axles)



Tandem Axle Group



Tridem Axle Group



Gross Vehicle Weight (GVW)

Obervations = 1,337

Mean = 57.3 kips

Static limit = 80.0 kips

Under-weight proportion = 98 %

Over-weight severity = 2.2 kips

Limit allowance = 10%

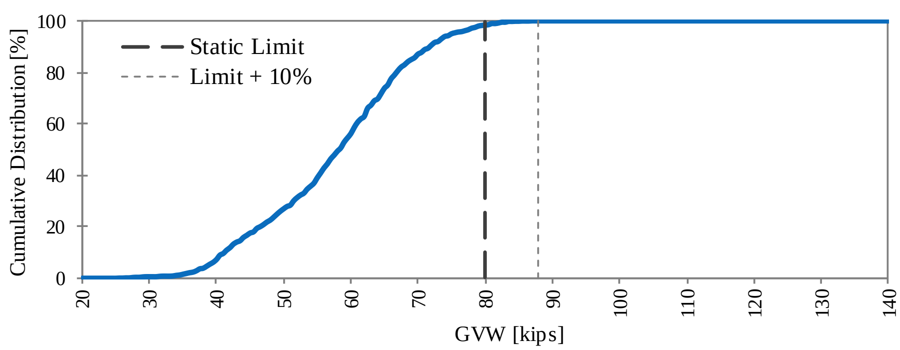


Figure 20: Performance Measures for the Comparison 3 Alternative Configuration

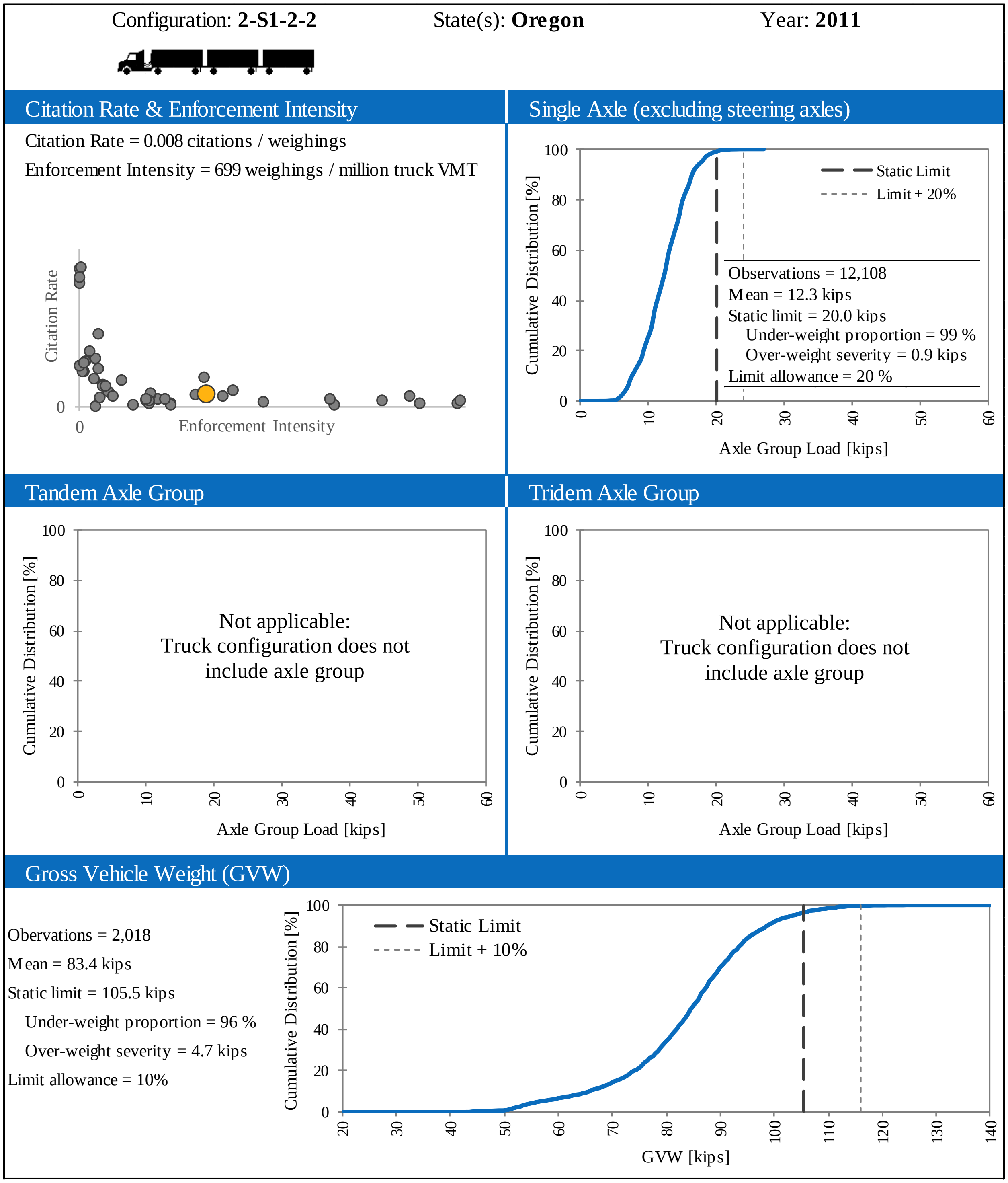


Figure 21: Performance Measures for the Comparison 4 Control Vehicle

Configuration: **2-S1-2** State(s): **Nevada-Utah** Year: **2011**

Citation Rate & Enforcement Intensity

Nevada

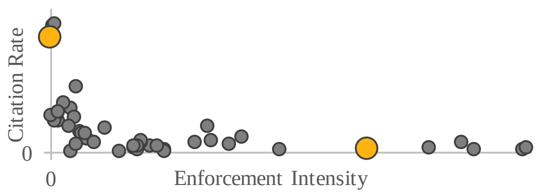
Citation Rate = 0.086 citations / weighings

Enforcement Intensity = 2 weighings / million truck VMT

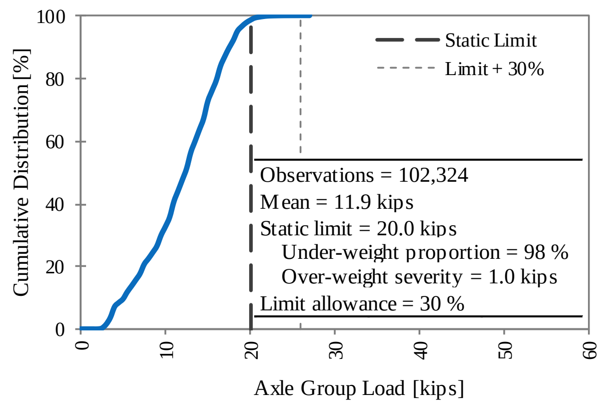
Utah

Citation Rate = 0.001 citations / weighings

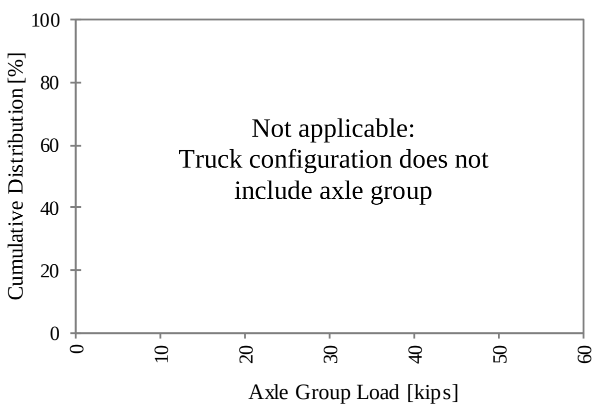
Enforcement Intensity = 1387 weighings / million truck VMT



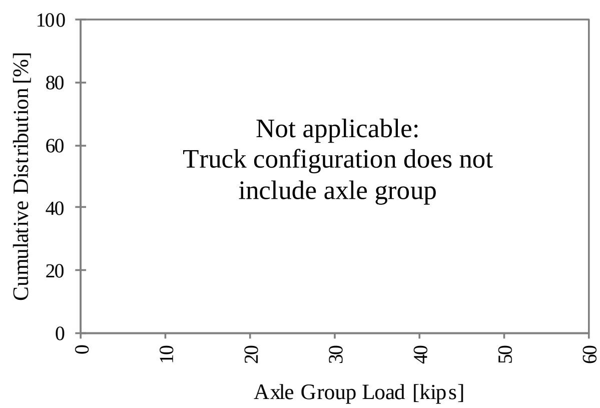
Single Axle (excluding steering axles)



Tandem Axle Group



Tridem Axle Group



Gross Vehicle Weight (GVW)

Obervations = 25,582

Mean = 57.4 kips

Static limit = 80.0 kips

Under-weight proportion = 96 %

Over-weight severity = 3.3 kips

Limit allowance = 15%

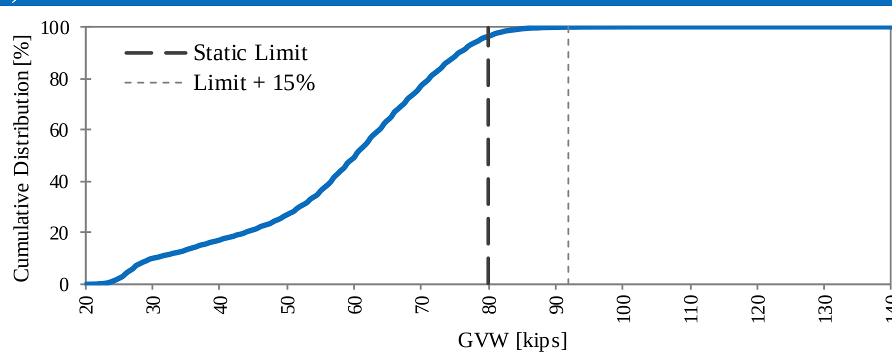


Figure 22: Performance Measures for the Comparison 4 Alternative Configuration

Configuration: **2-S1-2-2** State(s): **Nevada-Utah** Year: **2011**

Citation Rate & Enforcement Intensity

Nevada

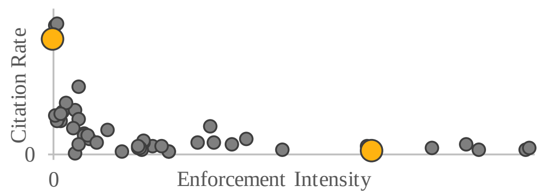
Citation Rate = 0.086 citations / weighings

Enforcement Intensity = 2 weighings / million truck VMT

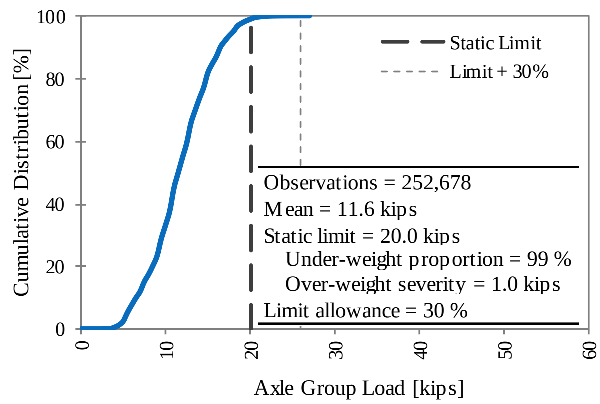
Utah

Citation Rate = 0.001 citations / weighings

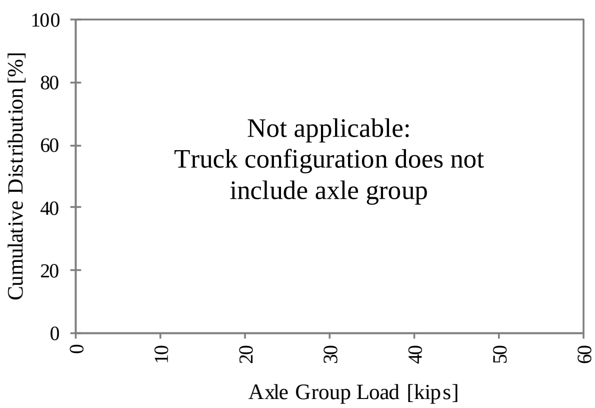
Enforcement Intensity = 1387 weighings / million truck VMT



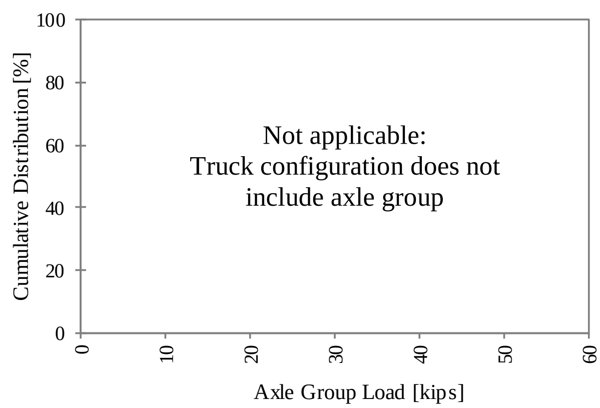
Single Axle (excluding steering axles)



Tandem Axle Group



Tridem Axle Group



Gross Vehicle Weight (GVW)

Obervations = 42,113

Mean = 79.7 kips

Static limit = 129.0 kips

Under-weight proportion = 100 %

Over-weight severity = 5.0 kips

Limit allowance = 15%

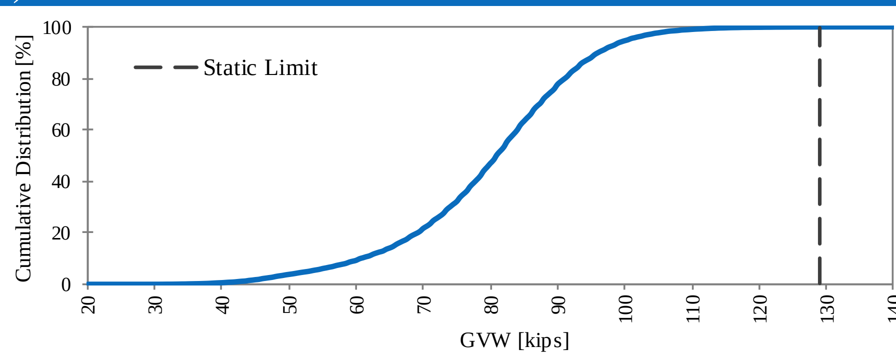


Table 21 summarizes the four comparisons using the performance measures defined above. Comparison 1 reveals a higher proportion of weight-compliant observations for tandem axle groups and GVW for the alternative configuration (3-S3 at 91,000 pounds) compared to the control vehicle (3-S2 at 80,000 pounds). Specifically, considering GVW, the proportion of weight-compliant observations is 95 percent for the 3-S3s compared to 90 percent for the 3-S2s. In terms of the average severity of overweight GVW observations, however, 3-S3s exhibited a higher level of severity than 3-S2s (6.0 kips overweight for 3-S3s compared to 3.4 kips overweight for 3-S2s).

Table 21: Summary of Performance Measures for Comparison 1 (Scenario 2)

	Weight Compliant Proportion (%)[1]				**Overweight Severity (kips)**			
	Single	Tandem	Tridem	GVW	Single	Tandem	Tridem	GVW
Control Vehicle  3-S2 @ 80K lb. (53’)	-	88	-	90	-	1.9	-	3.4
Alternative Configuration  3-S3 @ 91K lb. (53’)	-	90	93	95	-	2.4	4.5	6.0

[1] The percentages shown in the table are reported to the nearest percentage point as these values are used subsequently in the scenario analysis. The methodological assumptions and source data characteristics described in **Section 3.2** should be considered when interpreting these results.

Comparison 2a (**Table 22**), which analyzes WIM data obtained for Interstate highways, reveals a higher proportion of weight-compliant observations for tandem axle groups and GVW for the alternative configuration (3-S3 at 97,000 pounds) compared to the control vehicle (3-S2 at 80,000 pounds). Specifically, considering GVW, the proportion of weight-compliant observations is 89 percent for the 3-S3s compared to 87 percent for the 3-S2s. In terms of the average severity of overweight GVW observations, however, 3-S3s exhibited a higher level of severity than 3-S2s (6.0 kips overweight for 3-S3s compared to 4.6 kips overweight for 3-S2s).

In contrast, Comparison 2b analyzes WIM data obtained for non-Interstate highways. **Table 22** reveals that 73 percent of GVW observations are compliant for the alternative configuration (3-S3 at 97,000 pounds), compared to 93 percent of GVW observations for the control vehicle (3-S2 at 80,000 pounds). In terms of the average severity of overweight GVW observations, 3-S3s exhibited a higher level of severity than 3-S2s (8.0 kips overweight for 3-S3s compared to 6.4 kips overweight for 3-S2s).

Table 22: Summary of Performance Measures for Comparison 2 (Scenario 3)

	Weight Compliant Proportion (%)[1]				**Overweight Severity (kips)**			
	Single	Tandem	Tridem	GVW	Single	Tandem	Tridem	GVW
Comparison 2a: On Interstate								
Control Vehicle 3-S2 @ 80K lb. (53’)	-	87	-	87	-	2.5	-	4.6
Alternative Configuration 3-S3 @ 97K lb. (53’)	-	97	98	89[2]	-	2.8	3.5	6.0
Comparison 2b: Off Interstate								
Control Vehicle 3-S2 @ 80K lb. (53’)	-	91	-	93	-	3.2	-	6.4
Alternative Configuration 3-S3 @ 97K lb. (53’)	-	92	87	73 [2]	-	3.5	4.1	8.0

[1] The percentages shown in the table are reported to the nearest percentage point as these values are used subsequently in the scenario analysis. The methodological assumptions and source data characteristics described in **Section 3.2** should be considered when interpreting these results.
[2] The sum of the tandem and tridem limits plus a 12,000 pound steering axle is greater than the GVW limit for the alternative truck configuration. This may explain why the GVW-compliant proportion of observations is less than the GVW-compliant proportion of observations for the tandem and tridem axle groups.

The foregoing results provide some indication that an increase in the single-semitrailer truck configuration GVW limit may contribute to a higher proportion of GVW-compliant observations for single-semitrailer truck configurations in certain circumstances (namely for Comparisons 1 and 2a); however, this cannot be definitively concluded from the analysis as the comparison does not enable an assessment of the proportion of GVW-compliant observations for the control vehicle in the absence of the alternative configuration.

Comparison 3 (**Table 23**) reveals the same proportion of weight-compliant observations for single axles on the alternative configuration (2-S1-2-2 at 105,500 pounds) as for the control vehicle (2-S1-2 at 80,000 pounds), and nearly the same proportion of compliant observations for GVW. Specifically, considering GVW, the proportion of weight-compliant observations is 96 percent for 2-S1-2-2s compared to 98 percent for 2-S1-2s. In terms of the average severity of overweight GVW observations, 2-S1-2-2s exhibited a higher level of severity than 2-S1-2s (4.7 kips overweight for 2-S1-2-2s compared to 2.2 kips overweight for 2-S1-2s).

Table 23: Summary of Performance Measures for Comparison 3 (Scenario 5)

	Weight Compliant Proportion (%)[1]				Overweight Severity (kips)			
	Single	Tandem	Tridem	GVW	Single	Tandem	Tridem	GVW
Control Vehicle  2-S1-2 @ 80K lb. (2 @ 28.5')	99	-	-	98	0.8	-	-	2.2
Alternative Configuration  2-S1-2-2 @ 105.5K lb. (3 @ 28.5')	99	-	-	96	0.9	-	-	4.7

[1] The percentages shown in the table are reported to the nearest percentage point as these values are used subsequently in the scenario analysis. The methodological assumptions and source data characteristics described in **Section 3.2** should be considered when interpreting these results.

Comparison 4 (**Table 24**) reveals a similar proportion of weight-compliant observations for single axles and a higher proportion of underweight GVW observations when comparing the alternative configuration (2-S1-2-2 at 129,000 pounds) to the control vehicle (2-S1-2 at 80,000 pounds). Specifically, considering GVW, the underweight proportion of observations is nearly 100 percent for 2-S1-2-2s compared to 96 percent for 2-S1-2s. In terms of the average severity of overweight GVW observations, 2-S1-2-2s exhibited a higher level of severity than 2-S1-2s (5.0 kips overweight for 2-S1-2-2s compared to 3.3 kips overweight for 2-S1-2s).

Table 24: Summary of Performance Measures for Comparison 4 (Scenario 6)

	Weight Compliant Proportion (%)[1]				Overweight Severity (kips)			
	Single	Tandem	Tridem	GVW	Single	Tandem	Tridem	GVW
Control Vehicle  2-S1-2 @ 80K lb. (2 @ 28.5')	98	-	-	96	1.0	-	-	3.3
Alternative Configuration  2-S1-2-2 @ 129K lb. (3 @ 28.5')	99	-	-	100	1.0	-	-	5.0

[1] The percentages shown in the table are reported to the nearest percentage point as these values are used subsequently in the scenario analysis. The methodological assumptions and source data characteristics described in **Section 3.2** should be considered when interpreting these results.

The proportions of compliant GVW observations described in the foregoing comparisons also enable a system-wide consideration of enforcement effectiveness by applying these proportions to the truck travel estimates for the four applicable scenarios (i.e., Scenarios 2, 3, 5, and 6. As previously indicated, the five-axle tractor-semitrailer at 88,000 lb. GVW introduced by Scenario 1 is not analyzed because it cannot be isolated in the WIM dataset; the twin 33-foot double trailer configuration introduced by Scenario 4 is not analyzed because these configurations currently do not operate in the United States.).

Referencing

Table 25, the comparisons assume that these proportions (columns 2 and 3 in the table), which were observed at locations which facilitated direct comparisons of the control and alternative truck configurations, are applicable under base case and scenario traffic conditions. To extend these results to the scenarios and apply them to the VMT estimates for the control vehicles and alternative truck configurations in these scenarios (columns 4 and 5 in the table), the analysis assumes that the compliant GVW proportions observed at the selected sites (i.e., specific points on the network) also apply across the network as a whole. In other words, this assumption considers the weight-compliant proportion of GVW observations measured at a point to be the same as the weight-compliant proportion of VMT for the control and alternative truck configurations that would be observed over the network. Following these assumptions, for each of the four scenarios the analysis calculates the total (combined) proportion of weight-compliant VMT for the control vehicle and alternative truck configuration for the base case and compares this to the total (combined) proportion of weight-compliant VMT of the same two configurations under the scenario traffic conditions (column 6 in the table). Thus, the scenario analysis reveals the system-wide impacts on enforcement effectiveness—as measured by compliance outcomes—that could result from the introduction of the alternative truck configurations into the traffic stream.

Table 25: System-Wide Compliance Outcomes Based on the Scenario Analysis

	Weight Compliant GVW Proportion (%)		**2011 VMT (Millions of miles)**		
	Control Vehicle	**Alternative Configuration**	**Control Vehicle**	**Alternative Configuration**	**Estimated Underweight Proportion of VMT (%)**
Scenario 2: 3-S2 @ 80,000 lb. (control) *vs.* 3-S3 @ 91,000 lb. (alternative), Comparison 1					
Base Case	90	95	113,952	2,351	**90**
Scenario 2			101,054	16,438	**91**
Scenario 3 (on Interstate): 3-S2 @ 80,000 lb. (control) *vs.* 3-S3 @ 97,000 lb. (alternative), Comparison 2a					
Base Case	87	89	62,105	810	**87**
Scenario 3			53,250	9,689	**87**

	Weight Compliant GVW Proportion (%)		2011 VMT (Millions of miles)		
	Control Vehicle	Alternative Configuration	Control Vehicle	Alternative Configuration	Estimated Underweight Proportion of VMT (%)
Scenario 3 (off Interstate): 3-S2 @ 80,000 lb. (control) *vs.* 3-S3 @ 97,000 lb. (alternative), Comparison 2b					
Base Case	93	73	51,847	1,541	**92**
Scenario 3			44,363	9,152	**90**
Scenario 5: 2-S1-2 @ 80,000 lb. (control) *vs.* 2-S1-2-2 @ 105,500 lb. (alternative), Comparison 3					
Base Case	98	96	4,832	166	**98**
Scenario 5			6,131	3,281	**97**
Scenario 6: 2-S1-2 @ 80,000 lb. (control) *vs.* 2-S1-2-2 @ 129,000 lb. (alternative), Comparison 4 [1]					
Base Case	96	100	4,832	0	**96**
Scenario 6			6,093	3,084	**97**

[1] For this comparison, the seven-axle 2-S1-2-2 configuration operating at 129,000 lb. is considered a surrogate for the nine-axle 3-S2-2-2 configuration defined for Scenario 6.

Specifically,

Table 25 reveals the following:

- *Scenario 2:* For Comparison 1 (3-S2 @ 80,000 lb (control) *vs.* 3-S3 @ 91,000 lb (alternative)), the VMT for the control vehicle represents approximately 98 percent of the combined 3-S2 and 3-S3 VMT in the base case and 86 percent when introducing the alternative truck configuration into the traffic stream (as per Scenario 2). Applying the compliant GVW proportions to these VMT estimates, the estimated system-wide proportion of compliant VMT is 90 percent for the base case and 91 percent for Scenario 2.
- *Scenario 3 (on Interstate)*: For Comparison 2a (3-S2 @ 80,000 lb (control) *vs.* 3-S3 @ 97,000 lb (alternative) on Interstate), the VMT for the control vehicle represents approximately 99 percent of the combined 3-S2 and 3-S3 VMT in the base case and 85 percent when introducing the alternative truck configuration into the traffic stream (as per Scenario 3). Applying the compliant GVW proportions to these VMT estimates, the estimated system-wide proportion of weight-compliant VMT is 87 percent for the base case and Scenario 3.
- *Scenario 3 (off Interstate)*: For Comparison 2b (3-S2 @ 80,000 lb (control) *vs.* 3-S3 @ 97,000 lb (alternative) off Interstate), the VMT for the control vehicle represents approximately 97 percent of the combined 3-S2 and 3-S3 VMT in the base case and 83 percent when introducing the alternative truck configuration into the traffic stream (as per Scenario 3). Applying the compliant GVW proportions to these VMT estimates, the estimated system-wide proportion of weight-compliant VMT is 92 percent for the base case and 90 percent for Scenario 3.

- *Scenario 5*: For Comparison 3 (2-S1-2 @ 80,000 lb (control) *vs.* 2-S1-2-2 @ 105,500 lb (alternative)), the VMT for the control vehicle represents approximately 97 percent of the combined 2-S1-2 and 2-S1-2-2 VMT in the base case and 65 percent when introducing the alternative truck configuration into the traffic stream (as per Scenario 5). Applying the compliant GVW proportions to these VMT estimates, the estimated system-wide proportion of weight-compliant VMT is 98 percent for the base case and 97 percent for Scenario 5.
- *Scenario 6*: For Comparison 4 (2-S1-2 @ 80,000 lb (control) *vs.* 2-S1-2-2 @ 129,000 lb (alternative)), the VMT for the control vehicle represents 100 percent of the combined 2-S1-2 and 2-S1-2-2 VMT in the base case and 66 percent when introducing the alternative truck configuration into the traffic stream (as per Scenario 6). (As stated earlier, for this comparison, the 2-S1-2-2 configuration operating at 129,000 lb is considered a surrogate for the actual 3-S2-2-2 configuration defined for the scenario.) Applying the compliant GVW proportions to these VMT estimates, the estimated system-wide proportion of weight-compliant VMT is 96 percent for the base case and 97 percent for Scenario 6.

Overall, considering only the portion of VMT associated with the control and alternative configurations and accounting for the VMT changes predicted in each of the four scenarios relevant for this analysis, the results reveal limited impacts on the estimated proportion of total weight-compliant VMT expected under the scenario traffic conditions when compared to the base case traffic conditions.

Table 26 summarizes the results for each scenario considered.

Table 26: Expected Impacts on Enforcement Effectiveness by Scenario

Scenario	Estimated Enforcement Effectiveness (Underweight proportion of control vehicle and alternative configuration VMT): Base Case	Estimated Enforcement Effectiveness (Underweight proportion of control vehicle and alternative configuration VMT): Scenario	Expected Impact on Enforcement Effectiveness
Scenario 2	90	91	Limited impact
Scenario 3 (on Interstate)	87	87	No impact
Scenario 3 (off Interstate)	92	90	Limited impact
Scenario 5	98	97	Limited impact
Scenario 6	96	97	Limited impact

Identification of Statutes and Regulations

A final component of this study identifies statutes and regulations impacted by the potential allowance of alternative truck configurations on all roads and highways on which Surface Transportation Assistance Act (STAA) vehicles can now operate. The review focuses on relevant language contained in:

- 23 USC (Highways)
- 49 USC (Transportation and the corresponding regulations)
- 23 CFR Part 658 and 49 CRF Parts 390-399.

Table 2 in **Chapter 1** identifies the control and alternative truck configurations included in this Study. Commercial motor vehicles currently designated as STAA vehicles serve as the control vehicles needed to conduct the comparative analysis required in the 2014 CTSW Study. The six alternative truck configurations may require changes in the U.S. Code as well as the Code of Federal Regulations.

The methodology used in this analysis identifies currently relevant statutory or regulatory language and the corresponding impacts of incorporating the alternative truck configurations into Federal law and Federal regulation. **Appendix D** contains the particulars of these impacts. To summarize, these impacts principally involve:

- Enactment dates for all applicable sections in 23 USC 127, 49 USC Chapter 311 and 23 CFR Part 658 pertaining to vehicle size and weight limits, as identified in the analysis;
- Length provisions replacing references to the twin 28-foot and twin 28.5-foot trailer combination vehicles as STAA vehicles with the twin 33-foot trailer combination;
- The Federal Bridge Formula to enable operation of non-compliant configurations being assessed in the study; and
- The listing of States and vehicle and route specific allowances provided in Code of Federal Regulations Title 23, Part 658 Appendix C.

3.4 References

AASHTO, *Guide for Vehicle Weights and Dimensions*, Washington, DC: American Association of State Highway and Transportation Officials, 2001.

ASTM International, Standard Specification for Highway Weigh-in-Motion (WIM) Systems with User Requirements and Test Methods. In *Standard E1318-09* (pp. DOI: 10.1520/E1318-09), West Conshohocken, PA: 2009. www.astm.org.

Hanscom, F., *Developing Measures of Effectiveness for Truck Weight Enforcement Activities*, Washington, D.C.: National Cooperative Highway Research Program, 1998.

I-95 Corridor Coalition and FHWA, *Results of the Year 14 Oversize/Overweight Permitting Project, Best Practices Case Studies, Draft Report*, Washington, DC: 2008.

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APPENDIX A. REVISED COMPLIANCE DESK SCAN

CONTENTS

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CHAPTER 1 – INTRODUCTION

1.1 Purpose

This report presents a revised version of the Desk Scan (Subtask V.D.2) developed to support the Compliance Comparative Analysis (Task V.D) of the 2014 *Comprehensive Truck Size and Weight Limits Study* (2014 CTSW Study). This revised Desk Scan addresses the recommendations made by the National Academy of Science (NAS) Peer Review Panel concerning the originally submitted version of this scan.

The purpose of the revised Desk Scan is to:

- Reorganize and enhance the original Desk Scan; and
- Add any additional, relevant content that may have been identified since the submission of the original Desk Scan.

Specifically, the NAS Peer Review Panel recommended that the original Desk Scan be reorganized to address four issues:

- Analysis methods and the state of the practice in modeling the impacts of truck size and weight (TSW) enforcement on compliance;
- Identification and critique of data needs concerning TSW enforcement costs and effectiveness;
- Assessment of the current state of understanding of the impact and needs for future research, data collection, and evaluation in the area of TSW enforcement; and
- Quantitative results of past TSW enforcement studies.

1.2 Approach

To address these issues, the scan involves a comprehensive and review of literature regarding:

- Needs and traditional approaches for TSW enforcement, and the impacts of regulatory changes on enforcement programs;
- Enforcement costs and benefits;
- The effectiveness of TSW enforcement;
- The application and performance of TSW enforcement and compliance technologies; and
- Alternative approaches for achieving compliance.

The literature search includes documents published from around the world since 2000, supplemented by key historical material. Approximately 60 documents are cited in this scan;

these are sourced from: (1) engineering and scientific periodicals and journals; (2) conference proceedings; and (3) readily-available government and industry reports. Specific resources include:

- Transportation Research International Documentation (TRID)
- American Society of Civil Engineers
- University of Michigan Transportation Research Institute Library
- University of Manitoba Transport Information Group Library
- ScienceDirect
- NRC Research Press
- Transportation Association of Canada
- Heavy Vehicle Transport Technology Proceedings
- Federal Highway Administration (FHWA) library
- American Transportation Research Institute library
- National Transport Commission (Australia) library
- Australian Road Research Board library

A list of key documents follows:

- *Comprehensive Truck Size and Weight Study* by the U.S. Department of Transportation (USDOT), 2000 (2000 CTSW Study)
- Relevant special reports by the Transportation Research Board (TRB), namely *Special Report 267 Regulation of Weights, Lengths, and Widths of Commercial Motor Vehicles and Special Report 225 Truck Weight Limits: Issues and Options*
- Recent TSW reports conducted in Maine, Vermont, Wisconsin, and Minnesota
- *Moving Freight With Better Trucks* by the International Transport Forum
- NCHRP Web Document 13 entitled *Developing Measures of Effectiveness for Truck Weight Enforcement Activities*
- *National Heavy Vehicle Enforcement Strategy Proposal* by the National Transport Commission (Australia)

The scan emphasizes the enforcement of TSW limits; however, distinguishing enforcement activities concerning TSW from those directed at safety or credentials regulations was not always possible. Therefore, the review includes findings relevant to the general task of enforcing truck operations when these findings are also applicable to the enforcement of TSW limits.

1.3 Organization of this Report

This report synthesizes the literature concerning the costs and effectiveness of TSW enforcement from a programmatic perspective. Following this introduction, the report includes three chapters (organized as per the NAS Peer Review Panel recommendations):

- Chapter 2 provides a synthesis of analysis methods, which encompass the state of the practice in understanding and modeling the impacts of TSW enforcement on compliance.
- Chapter 3 provides an assessment of future research and data needs concerning TSW enforcement costs and effectiveness. (This chapter provides an integrated response to the second and third issues identified by the NAS Peer Review Panel.)
- Chapter 4 synthesizes quantitative results of past TSW enforcement studies.

In addition to these three chapters, this report contains one addendum which summarizes findings concerning alternative approaches for achieving compliance—principally those adopted in Australia. This topic falls outside the scope of the recommended issues to be addressed in this revised Desk Scan, yet provides context to its main findings. Finally, a complete list of references cited in this report is provided.

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CHAPTER 2 – SYNTHESIS OF ANALYSIS METHODS

This chapter summarizes three categories of enforcement program analysis methods evident in the literature: (1) performance-based methods, (2) empirical methods, and (3) meta-analysis and survey-based methods.

2.1 Performance-Based Methods

The literature contains several documents that discuss the application of performance-based methods to the design, implementation, and evaluation of TSW enforcement programs.

Hanscom (1998, pp. 3, 7) recognizes the need to develop performance measures to support better analysis and understanding of the cost and effectiveness of enforcement programs. This report states that "the effect of truck-weight enforcement programs is not known in terms of: (1) actual impacts on weight-law compliance, (2) effect on safety of truck operations, (3) pavement service life effects, or (4) cost-effectiveness of enforcement activity." Thus, Hanscom develops performance measures for truck weight enforcement activities. The focus of the research is to identify quantifiable measures that reflect the goals of an enforcement program (such as infrastructure protection) rather than using traditional indicators such as the number of trucks weighed, the number of violators detected, or the amount of fines collected. Initial development of candidate measures involved a survey of literature and state agencies, and the ranking of candidate measures in terms of: practicality of application, measurement reliability, support of statewide random sampling, absence of enforcement-induced bias, data collection methods capability, sensitivity to infrastructure damage, and applicability to data collection future technology. Candidate measures were then empirically validated using four independent field tests to determine the sensitivity of the measures to an imposed enforcement activity relative to baseline enforcement conditions. The validation revealed the weight enforcement program performance measures defined below:

- "*Gross weight violation, proportion*: The fraction (or percentage) of the total observed truck sample which exceeds the legal gross weight limit.
- *Gross weight violation, severity*: The extent to which average measured gross weights for the observed sub-sample of gross weight violators exceeds the legal gross weight limit.
- *Single-axle weight violation, proportion*: The fraction (or percentage) of the total observed truck sample with one or more axles which exceeds the legal single-axle weight limit.
- *Single-axle weight violation, severity*: The extent to which average measured single-axle weights for the observed sub-sample of single-axle weight violators exceeds the applicable legal limit.

- *Tandem-axle weight violation, proportion*: The fraction (or percentage) of the total observed truck sample with one or more tandems which exceeds the legal tandem-axle weight limit.

- *Tandem-axle weight violation, severity*: The extent to which average measured tandem-axle weights for the observed sub-sample of tandem-axle weight violators exceeds the applicable legal limit.

- *Bridge formula violation, proportion*: The fraction (or percentage) of the total observed truck sample which exceeds the legal Bridge Formula weight.

- *Bridge formula violation, severity*: The extent to which average measured Bridge Formula weights for the observed sub-sample of Bridge Formula violators exceeds the legal weight.

- *Excess ESALs [equivalent single axle loads], proportion*: The fraction (or percentage) of the total observed truck sample exhibiting Excess ESALs; i.e., ESALs attributable to the illegal portion of the individual single- or tandem-axle group.

- *Excess ESALs, severity*: The average value of Excess ESALs observed for the truck sub-sample exhibiting Excess ESALs."

Since Hanscom's work, several studies have advocated for the use of performance measures to analyze the cost and effectiveness of enforcement programs:

- URS (2005, pp. 56-58) describes what a performance-based approach to enforcement would involve and makes the distinction between inputs, outputs, and outcomes (i.e., performance). The authors list primary reasons for using performance measures as follows:

  Refining operational procedures
  Supporting investment decisions
  Prioritizing projects
  Providing information for outreach efforts
  Responding to legislative inquiries
  Providing input for organizational changes

The study identifies the following measures for inputs, outputs, and oucomes:

Input performance measures:
- Number of scale facilities
- Number of road miles covered by enforcement
- Number of troopers and inspectors
- Number of heavy VMT
- Annual tons of overweight delivery
- Percentage of vehicles with permits

Output performance measures:

- Number of stops per hour worked
- Number of inspections per day
- Number of citations issued
- Number of inspections per million commercial vehicle operator miles driven

Outcome performance measures (measured for each link and summarized for the entire system)

- Percentage of vehicles over legal gross
- Percentage of vehicles over legal axle loads
- Dollars saved from reduced pavement damage
- Dollars saved from reduced bridge damage
- Percent of vehicles operating legally
- Number of citations issued versus number of vehicles inspected (calculated separately for roadside, mobile, and fixed scale inspections)

Examples of applications of performance measures include the following:

Virtual weigh stations (VWS) can be used to identify repeat offenders and target enforcement accordingly. Historical data could be compared to see if targeted violators are becoming more compliant due to targeted enforcement and the application of VWSs in this manner.

Bridge vulnerability indices could be developed that prioritize targeted enforcement schedules by identifying bridge structures with low sufficiency ratings and low compliance rates on associated roads.

Pavement vulnerability indices could be developed in a similar way to bridge vulnerability indices.

Hourly violation rate tables could be developed that determine which hours are most likely to have overweight trucks; this information would support targeted enforcement.

- Fekpe *et al.* (2006, pp. 4-9) encourage the use of a performance-based compliance program and describe how this type of program may be designed and applied, particularly in the context of oversize/overweight (OS/OW) permitting. The authors indicate that a performance-based program should be robust and simple to administer, implement and monitor, and should use performance measures (or surrogate measures) that are easy to obtain using simple and quick roadside tests. They acknowledge that this may require an approach that differentiates trucks by configuration, commodity, and highway type in terms of enforcement and data collection. They propose issuing OS/OSW permits that restrict vehicles to designated routes defined by road class and that have been shown to be capable of supporting OS/OW loads contained in a permit. Permit fees should be related to infrastructure preservation but should be simple and practical to administer at a large national scale. The authors identify a permit fee option used in Saskatchewan that

requires carriers to demonstrate the economic benefit of operating at higher weights and calculating their permit fee as 50 percent of the associated increased profit resulting from increased weight productivity. The authors recommend a simpler approach where fees are graduated based on axle loads.
The authors state that enforcement of performance-based programs requires the use of transponders and other electronic methods in addition to enforcement officers, regulations, special conditions, education and industry communication, fines and penalties, and adjudication. They envision enforcement personnel collecting transponder data and transferring it to a central clearinghouse where reports could be produced to determine if the vehicle complied with the permit conditions. Traditional enforcement programs require drivers to possess a hard copy of the permit and present it to enforcement officers for inspection, whereas performance-based systems would use intelligent transportation systems (ITS) to automatically determine the legality of a vehicle without requiring manual inspection of hard copy permits. The authors suggest that violations should result in the permit being revoked and the vehicle being suspended from operation.

- URS (2013, pp. ii-vii) provides program recommendations as part of the development of a truck weight compliance business plan for Indiana. The plan recognizes the need for an outcome-driven decision-making course that: (1) addresses the needs of the freight transport industry; (2) helps minimize infrastructure damage; (3) addresses safety issues; (4) meets federal and state mandates regarding truck weight enforcement; and (5) supports the Moving Ahead for Progress in the 21st Century (MAP-21) transportation bill. In general, the aim of the plan is to reduce the infrastructure damage cost burden and shift the burden away from taxpayers through appropriate fine and permit structures.

- DalPonte *et al*. (2015, pp. 3-5) use the size and weight enforcement program from Oregon to establish a performance management approach that may improve federal oversight of states' size and weight programs. Specifically, they evaluate Oregon's existing performance measures, which include:

  Truck-at-fault crashes;
  Inspections leading to a driver being placed out-of-service for a critical safety violation;
  Trucks weighed in motion and pre-cleared by Green Light (a program allowing registered vehicles with transponders to bypass static scales);
  Trucks weighed on static scales;
  Total trucks weighed (the sum of Green Light and static scale weighings); and
  Total weight-related enforcement actions (the sum of weight citations and warnings issued);
  Weight-mile tax audit recoveries. (Unlike nearly all other states, Oregon uses a weight mile tax rather than a fuel tax for trucks; the tax is levied based on the weight and number of axles and number of miles driven within the state.)

  The performance measures are considered as they relate to the following three enforcement program outcome relationships:

"As more truck drivers are placed out-of-service for critical safety violations, truck-at-fault accidents decline."

"As more trucks are weighed and more scale crossings recorded, auditors recover more weight-mile tax dollars."

"As more trucks are weighed, more weight citations are issued."

Their analysis recommends that Oregon retain their existing performance measures but supplement them with another measure to quantify the quality of services provided by the Department of Transportation staff to trucking firms. This could be in the form of the number of online inquires and calls answered by service representatives. Additionally, it is recommended that these measures be related to vehicle miles traveled to highlight enforcement efficiency.

2.2 Empirical Methods

he literature provides examples of the application of empirical methods to improve understanding of enforcement costs and the effectiveness of TSW enforcement activities. Specific methods evident in the literature include the use of scenario analyses (i.e., understanding compliance under varying enforcement conditions), pilot studies, and the use of weigh-in-motion (WIM) or vehicle inspection data to assess regulatory compliance.

Scenario analyses offer one way to understand the enforcement program performance and overcome data limitations and analytical uncertainties. Hanscom (1998, p. 13) integrates the proposed performance measures (identified above) into a software tool which uses them as the basis for statistical comparisons between two enforcement conditions (i.e., scenarios with and without enforcement activity). These comparisons can be made at a statewide/regional level, along a corridor, or at a specific location. Similarly, Strathman and Theisen (2002, pp. vii-viii) investigate the effectiveness of enforcing truck weights at a fixed weigh station on an interstate highway (Interstate 5) by collecting WIM data from three nearby sites: one site on the same interstate highway and two sites on potential by-pass routes. Data were collected prior to, during, and after an extended scale closure. Jones (2012, pp. 3-4) cites a study in Tasmania which applied a similar approach to investigate the effect of truck weight enforcement on the frequency of overweight violations detected.

Rooke *et al.* (2006, p. 21) evaluate the cost of enforcement activities for the European Union's project REMOVE which seeks to provide a framework for WIM systems to reduce danger and damage caused by overweight vehicles. The authors determine enforcement costs for three enforcement scenarios: (1) manual selection; (2) WIM for pre-selection; and (3) WIM for direct enforcement. Finally, Australia's National Transport Commission (2009, pp. ES-1, 2) estimates the costs and benefits over a five-year period of the National Heavy Vehicle Enforcement Strategy which was proposed in 2007 (National Transport Commission, 2007). Since considerable uncertainty exists when estimating benefits, three benefit scenarios (low, medium, high) were developed as part of the estimation process. Based on available data and experience, the low benefit scenario assumed a one percent reduction in heavy vehicle crashes, a one percent reduction in road damage, and a one percent improvement in enforcement efficiency. The medium and high benefit scenarios were calculated based on three and five percent improvements in these areas, respectively.

The use of pilot studies has also been used as an empirical method to analyze enforcement effectiveness. The TRB (2002) recommends this method for conducting various types of TSW policy analysis because of the magnitude of uncertainty associated with the impacts of changing TSW regulations. The FHWA (2012a, pp. 21-22) adopted this approach in the Vermont pilot program, which saw an increase in TSW limits on Vermont's interstate highways for a one-year period, including allowance of a 6-axle tractor semitrailer limited to 99,000 lbs. gross vehicle weight. Among other objectives, the program enabled investigation of enforcement levels and overweight axles as a potential contributor to truck crashes.

An alternative empirical method for analyzing the effectiveness of truck weight enforcement relies on the use of WIM data to directly assess regulatory compliance, without specific regard for enforcement method. Regehr et al. (2010, pp. 8-9) assess regulatory compliance of three long truck configurations (Rocky Mountain doubles, Turnpike doubles, and triple trailer combinations) operating under special permit in the Canadian Prairie Region. The special permits contain vehicle, driver, operational, and network-related regulatory conditions. These vehicles are predominantly used to haul cubic (low density) freight. The authors use WIM data to assess compliance with (static) vehicle and axle weight regulations.

More recently, empirical research has also attempted to link overweight trucking and safety. Siekmann and Capps (2012, p. 19) provide interim findings to Federal Motor Carrier Safety Administration (FMCSA) concerning heavy and overweight vehicle defects, based in part on data obtained about overweight trucks from a nationwide data collection effort facilitated by the Commercial Vehicle Safety Alliance (CVSA).

2.3 Meta-Analysis and Survey-Based Methods

The literature contains a number of studies that address enforcement costs and effectiveness through a compilation and analysis of survey and/or literature findings. In certain cases, this approach is adopted because the primary objective of these studies was to conduct a meta-analysis rather than primary research. Principal examples of this are the recent synthesis of literature concerning TSW enforcement practices and performance produced by Carson (2011), and a report by Australia's National Transport Commission (2011a) which synthesizes international best practices for achieving regulatory compliance.

In other cases, the analysis of survey and/or literature findings are applied to assess enforcement effectiveness because of the lack of empirical data on the subject. Straus and Semmens (2006, pp. 24-25, 55-58) estimate the cost of overweight vehicle travel on Arizona highways. To support this analytical work, the authors provide results from a survey of 25 states concerning their experiences with truck weight enforcement and overweight trucking. Similarly, Ramseyer et al. (2008, pp. 31-53) conduct a survey of all 48 contiguous states concerning enforcement and compliance, with 38 states providing responses (although not every question was answered by each respondent). The survey results provide useful information about truck weights and overloading. Cambridge Systematics (2009a) interviews nine states to determine best practices in the deployment of roadside enforcement technologies. Finally, Honefanger et al. (2007)

summarize and evaluate procedures and technologies for enforcing TSW laws in Europe (Belgium, France, Germany, the Netherlands, Slovenia, and Switzerland), based on an international scanning tour which involved interviews with TSW enforcement officials from each of these countries.

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CHAPTER 3 – ASSESSMENT OF FUTURE RESEARCH AND DATA NEEDS

This chapter summarizes recommendations for improving the understanding of the costs and effectiveness of TSW enforcement programs, citing international, national, and state-specific studies. The literature contains several studies that make recommendations concerning how TSW enforcement programs may achieve their compliance goals. Many of these recommendations refer to a general lack of reliable data on truck weights and the effectiveness of truck weight enforcement programs; therefore, specific data needs and potential data sources are identified. Finally, the literature discusses the ongoing debate about the range of strategies considered to deliver TSW enforcement programs—from deterrence-based enforcement methods to approaches aimed at incentivizing compliance.

TRB (1990, pp. 135-143) recommends the following congressional actions to improve enforcement of truck weight laws: (1) direct federal funding of state enforcement; (2) imposition of federal penalties for violations of federal weight limits on interstate highways, or alternatively, mandating of minimum state penalties; (3) federal provision for assessing penalties against parties for placing overweight shipments into commerce; (4) federal support for state measures to place overweight trucks out of service until they are offloaded; (5) development of educational programs for judges and prosecutors regarding the overweight problem; and (6) creation of a federally managed program for systematic collection of data on violators that would identify the responsible carrier or other operator so repeat offenders could be targeted.

A second TRB report on TSW regulation (2002, pp. 170, 175, 183) echoes many of the initial recommendations made in 1990. This report indicates that "few evaluations" have been conducted on the impact of enforcement strategies on the frequency and magnitude of weight violations. Moreover, the report suggests that effective adoption of enforcement technologies has the potential to induce "substantial cost reductions" for enforcement programs, regardless of whether changes to TSW limits occur. This lack of evidence stems from an absence of available data and the inability to implement statistically valid truck weight sampling plans. Specially-permitted oversize and overweight vehicles require particular attention within enforcement programs. Recommendations to develop information systems to support compliance assessment, enforcement effectiveness and targeting, the benefits of effective enforcement, and program evaluation are evident in the literature since at least the early-1990s, namely from the TRB *Truck Weight Limits Study* (1990) and a report by the Office of Inspector General (1991).

TRB (2002, p. 176) summarizes the proposed enforcement reforms made by the Office of Inspector General (OIG) Report (1991). This report recommends the following measures: (1) develop a program to produce the data needed to quantify the extent of overweight traffic; (2) require that states formulate annual enforcement plans and demonstrate the effect of enforcement on violations; (3) develop standards and technological improvements for WIM systems; (4) restrict state use of divisible-load permits and multiple-trip non-divisible load permits on the interstate system; (5) evaluate fine structures; and (6) promote non-traditional enforcement techniques (such as the inspection of shipping and receiving logs for illegal loads).

Recommendations for more targeted enforcement programs have also been evident internationally (notably in Australia and Europe). Allen (2002, p. 177) provides two principles governing targeted TSW enforcement. First, the entire population of heavy vehicles should be monitored to control the system and provide the range of compliance rates within the industry. This enables a regulator to identify current and future outliers within a dynamic industry. Second, targeted enforcement should identify and capture high-risk offenders that fall outside established regulatory limits. This principle relies on appropriate processes to remove offenders from the industry or bring their behavior back into accepted norms. Moreover, Quinlan (2002, p. 242) indicates that a coordinated and targeted compliance approach in the road transport industry is needed to overcome fragmented regulatory approaches. Fragmented approaches are "unfair, inconsistent, confusing […] and offer too many avenues for calculated evasion." Rooke *et al.* (2006, p. 51) reveal that the current practice of applying liability to the driver and/or operator is not conducive to achieving compliance across the haulage industry. They indicate that the road transport industry is "generally in favor" of taking the problem-solving approach to enforcement which involves targeting carriers with a history of non-compliance.

URS (2005, pp. 33-52) identifies the key issues to be addressed to improve enforcement effectiveness in a statewide commercial vehicle weight compliance strategic plan developed for Minnesota. These issues include:

- Trucks by-passing fixed weigh stations;
- Declining enforcement resources and/or fixed resources with increasing truck volumes;
- The need for enforcement programs to be performance-based and to use performance measures to guide decision-makers;
- Inability to measure compliance;
- Apparent ineffectiveness of fixed weigh scales for weight enforcement shortly after the scale opens;
- Potential for portable scales to be used on lower volume highways;
- Potential for using WIM devices as weight enforcement tools rather than exclusively for planning purposes;
- Importance of WIM maintenance and accuracy and the required resources to maintain adequately operating WIMs;
- The need to enhance traditional enforcement approaches to allow field inspectors to determine if an overweight vehicle has a permit prior to pulling the vehicle over; and
- The need to establish and refine practical performance measures for weight enforcement that are effective and affordable.

A more recent study by URS (2013, pp. ii-vii) provides program recommendations as part of the development of a truck weight compliance business plan for Indiana. The report recommends:

- Maintaining existing fixed scales and restoring functionality at one scale that had been decommissioned;
- Expanding the functionality of the existing central database server;
- Upgrading several existing WIM sites to virtual WIM sites;
- Strengthening coordination between agencies involved in truck weight compliance within the state;
- Analyzing the impact of a recent regulatory change in Indiana which permits divisible loads up to 120,000 pounds;
- Changing the current permit fee structure to one which reflects the damage caused by varying axle loads; and
- Building fixed weigh scales in regions in the state where this infrastructure is currently lacking.

Specific data needs and sources have been identified in several studies. In a review of federal TSW enforcement programs, the USDOT (2000, pp. VII-4 to VII-6) notes a general improvement in the level of enforcement activity resulting from requirements for states to develop and certify state enforcement plans (SEPs) and the adoption of technologies such as WIMs for pre-screening. These state-submitted data have been used to track enforcement costs and effectiveness, principally in terms of the number of trucks weighed, the number of citations issued, violation rates, and requirements for vehicle offloading and load shifting. Quantifying the degree of non-compliance "continues to be difficult." URS (2005, p. 58) identifies examples of existing data sources that could support performance-based enforcement programs. These sources include: truck traffic data (*e.g.*, vehicle classification sites, traffic volume counters, and WIM scales); relevant evidence data; pavement and bridge sufficiency ratings; and safety data. Fekpe *et al*. (2006, p. 4) recognize the need to collect data that differentiates trucks by configuration, commodity, and highway type. Finally, a more recent report by the OECD (2011, p. 298) also recognizes the value of applying WIM to support truck weight enforcement programs. This report states that WIM technologies have the potential to deliver more detailed, continuous data about weight compliance, specifically by utilizing axle spacing measurements to isolate the compliance record of higher capacity configurations.

The recommendations and research and data needs identified in the foregoing literature appear to reflect an ongoing debate about how to best improve the effectiveness of truck weight enforcement programs. Thomas (2002, pp. 125, 129) asserts that the debate about what constitutes effective enforcement will remain unresolved. In essence, one side of this debate encompasses the view that more enforcers mean more enforcement, and more enforcement is more effective. The alternative view favors enforcement effectiveness gained through court-delivered sanctions, which should direct behaviors towards compliance. The author suggests that "the most important key to effective enforcement is the engaging of all industry parties to play a more proactive role in managing all facets of their business operations to achieve compliance with their legislative obligations."

Australia's National Transport Commission (2011a, pp. iii-iv) discusses this 'enforcement *versus* compliance' debate more extensively in its synthesis of international best practices for achieving regulatory compliance. Borrowing from compliance and regulatory practices in fields other than trucking, the report concludes that the dualistic enforcement (deterrence) *versus* compliance thinking has evolved into a wider range of options, with no internationally-accepted best practice. More specifically, the report identifies seven regulatory strategies, including:

- Rules and deterrence, which emphasizes an "adversarial style of enforcement" and penalties for rule-breakers;
- Advice and persuasion, which emphasizes co-operation rather than confrontation to prevent harm and avoid sanctioning;
- Responsive regulation, which features a combination of the two foregoing strategies;
- Smart regulation, which expands on responsive regulation by emphasizing the role of the market and society in acting as a regulator;
- Metaregulation, which requires regulated entities to submit compliance plans for approval, with the regulator acting as a risk manager;
- Risk-based regulation, which emphasizes the need to adjust the regulator's response to non-compliance based on the risk that the non-compliant event poses to the regulator's objectives; and
- Criteria-based strategy, which enables a wide range of compliance and enforcement responses, chosen based on consideration of pertinent criteria.

The report also identifies five compliance assurance tools, including:

- Tools used prior to a regulated activity (e.g., licenses, permits);
- Tools designed to encourage or reward compliance (e.g., education, advice);
- Tools that remind an entity of regulatory responsibility (e.g., prohibition notices);
- Tools involving penalties or sanctions; and
- Tools that use rewards and positive motivation to encourage behavioral change.

Finally, the report identifies an emerging approach known as informational regulation, which provides information on the operations of regulated entities to affected stakeholders, who then exert pressure on the regulated entity to improve compliance.

The National Transport Commission's report concludes that there is a need to improve the scope of tools used to achieve compliance, by drawing strategically from those tools at the bottom and top of the 'enforcement pyramid' (which emphasize compliance and deterrence, respectively). Specifically, the need for more reliance on rewards-based tools and informational regulation is identified. When selecting an appropriate mix of tools, however, regulators should be aware that some combinations of tools may be counter-productive.

The OECD (2011, pp. 281-282) appears to concur with the National Transport Commission's policy and programmatic recommendations concerning TSW enforcement and compliance. The OECD quotes an Australian report by McIntyre and Moore (2002, p. 1), which lists the following issues with the traditional truck weight enforcement approaches:

- "Fines, no matter how high, will not have a sufficient deterrent effect when the chance of detection is slight and the potential profits from offending are high.

- Targeting only the truck driver and operator has no deterrent impact on the many 'off-road' parties who have a significant influence on on-road compliance and leads to a perception amongst drivers and operators that they are being treated unfairly.

- In an industry characterized by high levels of competition resulting from low barriers to entry and a large number of small operators, the survival of operators who attempt to achieve levels of compliance higher than industry standards will be threatened.

- A culture founded on confrontation between the regulator and the regulated is not conducive to promoting voluntary compliance."

The OECD report also suggests (p. 295) that the level of compliance achieved depends on:

- "The degree to which the target group knows of and comprehends the rules";

- "The degree to which the target group is willing to comply—either because of economic incentives, positive attitudes arising from a sense of good citizenship, acceptance of the policy goals, or pressure from enforcement activities"; and

- "The degree to which the target group is able to comply with the rule."

The report identifies consistent, targeted enforcement as one of a set of "compliance-enhancing tools," which includes incentives-based strategies, training of enforcement officers, industry education and communication, monitoring compliance levels and effectiveness, and conducting ongoing research.

Australia, in particular, has pursued alternative approaches to achieving regulatory compliance as recommended by the National Transport Commission (2011a) and OECD (2011) reports. **Appendix A** contains further details on Australia's experience.

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CHAPTER 4 – SYNTHESIS OF QUANTITATIVE RESULTS

This chapter provides a synthesis of quantitative results concerning the costs and effectiveness of TSW enforcement programs. It contains four sections: (1) costs and benefits of TSW enforcement programs; (2) the effectiveness of TSW enforcement programs; (3) the effectiveness of on-road enforcement methods; and (4) regulatory changes and the effectiveness of TSW enforcement. While quantitative results are of primary interest, qualitative descriptions of operations and effectiveness of these methods are also included.

4.1 Costs and Benefits of TSW Enforcement Programs

There is relatively little directly relevant information in the literature about the programmatic costs of conducting TSW enforcement. The previous *Comprehensive Truck Size and Weight Stud*y conducted by the USDOT provides the most detailed assessment of TSW enforcement program costs (and related activities) available. Using state-reported data, the USDOT (2000, pp. VII-6 to VII-7) reports nationwide statistics as follows:

- Total nationwide expenditures on TSW enforcement reported by states in 1995 was approximately $281 million.
- Total nationwide weighings reported by states ranged from approximately 105 million to approximately 170 million between 1985 and 1995.
- Total nationwide non-WIM weighings (i.e., fixed platform, portable, semi-portable) reported by states ranged from approximately 97 million to approximately 124 million between 1985 and 1995.
- Total nationwide load-shifting and offloading vehicles reported by states ranged from approximately 478,000 to approximately 579,000 between 1985 and 1995.
- The average nationwide cost per non-WIM weighing was approximately $2.50 in 1995.

Other studies approach the assessment of enforcement costs and benefits more generally, often reporting the cost imposed by overloaded vehicle travel or the benefits (and sometimes costs) resulting from the elimination of overloaded vehicles. Citing TRB (1990), TRB (2002, p. 174) indicates that if no change in the quantity of truck freight occurred, the elimination of illegal overloads could reduce pavement costs by $160 million to $670 million per year in the United States. Further, “rigorous enforcement” would cause a 0.5 to 2.5 percent increase in annual vehicle miles traveled by large trucks, corresponding to an annual cost to shippers of $500 million to $2.5 billion. These figures may encourage shippers to “pay the added pavement costs generated by their overloaded trucks instead of reducing their loads.”

Stephens *et al.* (2003, pp. 143-148) use WIM data to determine the pavement damage caused by overweight vehicles each month and identify the vehicle configurations and travel characteristics (*e.g.*, time, direction) contributing the most to pavement damage. This information was used to deploy officers to the top five sites in terms of damage caused by overweight trucks. In the subsequent year of targeted enforcement using this information, pavement damage from overweight vehicles decreased by 4.8 million ESAL-miles (approximately $500,000 in savings) and the number of overweight vehicles at the WIM locations decreased by 20 percent. Due to the short timeframe of the program (i.e., one year to identify the top five locations and one year to target enforcement) the authors caution the extrapolation of these results to long-term horizons and acknowledge that there are year-to-year changes in overweight vehicle operations irrespective of enforcement activity. The authors find that there were increases in overweight vehicles at other enforcement sites that had lower enforcement activity due to shifting resources based on WIM information; however, these were generally low-volume sites.

Straus and Semmens (2006, pp. 24-25, 55-58) estimate the cost of overweight vehicle travel on Arizona highways. As a basis for the range of estimates presented, the authors use cost figures attributed to all commercial vehicles from Arizona's highway cost allocation model and the proportion of federal estimates of nationwide pavement maintenance costs allocated to Arizona. These figures indicate that pavement damage costs attributable to commercial vehicles (including overweight trucks) in Arizona range between $210 million and $420 million per year. From this starting point, the authors factor in costs specifically attributed to overweight trucks (based on an estimate that 15 percent of trucks operate overweight), the disproportionate damage caused by heavier axles, and revenues generated by heavy vehicle travel. The authors conclude that "overweight vehicles impose somewhere between $12 million and $53 million per year in uncompensated damages to Arizona highways." Arizona spends nearly $6 million on mobile enforcement activities, which are in part directed at deterring overweight trucking. Thus, if doubling the budget for mobile enforcement was "50 percent effective toward the objective of eliminating illegally overweight vehicles," annual pavement damage savings would range from $6 million to $27 million. These figures translate into a range of benefit-cost ratios between one and four or five.

Australia's National Transport Commission (2009, pp. ES-1, 2) estimates the costs and benefits over a five-year period of the National Heavy Vehicle Enforcement Strategy which was proposed in 2007 (National Transport Commission, 2007). This strategy aimed to promote consistent, effective and efficient enforcement in heavy vehicle transport law in Australia. In particular, the strategy focused on increased use of intelligence-driven enforcement and coordinating practices between Australian states as they implement reforms such as the chain of responsibility principle.

The National Transport Commission indicates that the main costs associated with implementation of the strategy relate to the collection and analysis of data and the establishment of national coordination practices. In total, costs to the enforcement agency (in 2008 Australian dollars) summed to $2.6 million in year one and rose to $3.1 million per year thereafter. Benefits gained by more targeted enforcement included heavy vehicle crash reduction, reduced road damage from overloading, and improved enforcement cost efficiencies. Since considerable uncertainty exists when estimating benefits, three benefit scenarios (low, medium, high) were developed as part of the estimation process. Based on available data and experience, the low benefit scenario assumed a one percent reduction in heavy vehicle crashes, a one percent reduction in road damage, and a one percent improvement in enforcement efficiency. The medium and high benefit scenarios were calculated based on three and five percent improvements in these areas, respectively. Under these scenarios, in 2008 Australian dollars, the following annual benefits were calculated: (1) between $13 million and $65 million for reduced heavy vehicle crash costs; (2) between $0.6 million and $2.8 million for reduced road wear; and (3) between $1.2 million and $6 million for improved enforcement efficiency. In terms of net present value over the five-year period (using a four percent discount rate); the strategy would see a net benefit ranging from $38 million to $246 million, corresponding to a benefit-cost ratio of between 4 to 1 and 20 to 1. Even a 50 percent increase in costs would see net benefits and benefit-cost ratios between 2.6 to 1 and 13 to 1.

Rooke *et al.* (2006, pp. 21-25) evaluate the cost of enforcement activities for the European Union's project REMOVE which seeks to provide a framework for WIM systems to reduce danger and damage caused by overweight vehicles. The authors determine enforcement costs (shown in **Table 27**) for three enforcement scenarios: (1) manual selection; (2) WIM for pre-selection; and (3) WIM for direct enforcement. These figures assume that the number of overloaded vehicles remains the same regardless of the enforcement scenario and that WIMs used for direct enforcement require a higher level of accuracy than those used for pre-selection.

Table 27: Costs to Enforcement Agency by Enforcement Scenario

Scenario	Enforcement cost per year	Enforcement cost per year per officer	Enforcement cost per year per overloaded vehicle
Manual selection	€ 160,000	€ 53,333	€ 145
WIM for pre-selection	€ 422,500	€ 70,417	€ 75
WIM for direct enforcement	€ 322,150		€ 3

Rooke *et al.* also estimate the cost of damage to infrastructure by overloaded vehicles in the European Union. Due to limited research the term infrastructure refers only to roadways. The estimated cost of damage incurred from overloaded vehicles is composed of the cost of road maintenance and the corresponding cost of traffic delays caused by road maintenance. Using the Netherlands data to estimate damage costs and assuming the same percentages hold for the other 14 EU countries, the authors reason that the EU spends from €239 million to €557 million on repairing road damage caused by overloaded vehicles. Considering only the national road networks the cost ranges from €153 million to €227 million. For comparison, the road maintenance budget of the 15 EU countries combined is €10,500 million. The authors conclude that the "possible level of damage to the infrastructure caused by overloaded vehicles is significant." As well, the potential savings from using correctly loaded goods vehicles is significant. They recommend member states set targets to "reduce maintenance budgets by effective compliance strategies for overloaded vehicles."

URS (2013, p. ii) develops a business plan for Indiana's truck weight compliance program. The report cites proven performance of a pilot virtual WIM site in the state. Based on data collected at this site, the report estimates that a "conservative minimum estimate of $850,000 per year in pavement preservation can be saved across the state network with a comprehensive compliance program". This estimate could range as high as $3 million per year (or even higher). The report also estimates that the cost of a virtual WIM installation would be recovered by the enforcement agency through pavement damage reduction in three to six years.

4.2 Effectiveness of TSW Enforcement Programs

The costs and benefits of TSW enforcement programs provide one indication of program effectiveness; however, the literature also assesses effectiveness by attempting to quantify the magnitude of overweight trucking.

In one of the most comprehensive reviews of issues concerning truck weight limits, the TRB (1990, p. 141) finds that "reliable estimates of the magnitude and frequency of illegal overloads are not available." Available WIM data collected in six states between 1984 and 1986 reveals that "about 10 to 20 percent of all combinations are operating illegally overweight without a permit." A survey of truck weight enforcement personnel corroborates this finding by suggesting that "more than 10 percent but less than 25 percent of trucks are overloaded."

A more recent TRB report (2002, pp. 171-172) on TSW regulation draws similar conclusions, stating that estimates of operating weights of trucks are "fragmentary and inconsistent." According to state officials, overloading problems appear to be concentrated in certain industry segments which haul bulk, high density (i.e., weigh-out) commodities. The authors cite estimates of actual non-compliance made by four independent studies.

- Grenzeback et al. (1988) "estimate that 15 percent of large trucks would exceed axle weight or GVW limits on a segment of interstate highway where enforcement was not taking place." This study also suggests that a "minimum" violation rate of six percent exists at fixed scales.
- A study by the FHWA (1993) indicates that "only 0.6 percent of trucks exceed gross vehicle weight limits at weigh stations." This number is affected by overweight trucks that "routinely avoid the stations."
- Hajek and Selsneva (2000) estimate that 12 percent of tandem axles exceeded the federal (U.S.) maximum of 34,000 lbs., according to data collected at several hundred WIM sites.
- Unpublished USDOT estimates attribute "10 percent of all miles of travel by trucks with three or more axles to vehicles weighing more than 80,000 lbs." This includes both legal and illegal overload operations. No information is provided in the report about when these data were collected.

The USDOT (2000, pp. VII-6 to VII-7) reports nationwide citation rates (weight citations per non-WIM weighing) ranging from 0.006 and 0.007 in the period from 1985 and 1995, based on state-reported truck weight enforcement activity data. In each of the years reported, the weighings occurring at fixed weigh scales exceeded 97 percent of all non-WIM weighings. A citation rate provides an indication of the magnitude of the overweight trucking problem, but may not be representative of all trucking activity.

More recent studies quantify the extent of overweight trucking by using WIM data to isolate specific truck configurations and by analyzing data obtained from truck safety inspections. Regehr *et al.* (2010, pp. 8-9) assess regulatory compliance of three long truck configurations (Rocky Mountain doubles, Turnpike doubles, and triple trailer combinations) operating under special permit in the Canadian Prairie Region. The special permits contain vehicle, driver, operational, and network-related regulatory conditions. These vehicles are predominantly used to haul cubic (low density) freight. The authors use WIM data to assess compliance with (static) vehicle and axle weight regulations. The weight analysis, which was based on one year of (dynamic) weight data from a single WIM located on the Trans-Canada Highway, reveals that 99 percent (22,823 of 23,092) of Rocky Mountain doubles and Turnpike doubles comply with their static weight limit. Similarly, 99 percent of the dynamically measured single, tandem, and tridem axle weights were compliant with static weight limits. Steering axles were found to be compliant between 92 and 95 percent of the time. The analysis does not relate compliance to particular on-road enforcement methods.

Siekmann and Capps (2012, p. 19) provide interim findings to FMCSA concerning heavy and overweight vehicle defects. Based on data obtained about overweight trucks from a nationwide data collection effort facilitated by the CVSA and an additional, smaller but more detailed dataset, the authors conclude the following:

- Of the 1,873 Level 1 inspections performed on overweight vehicles in 18 states over a six-month period, a vehicle out-of-service (OOS) violation was found on 44.79 percent of the vehicles. This rate is higher than the national OOS rate of 27.23 percent.

- Brake-related defects were the main reason for a vehicle being placed OOS, "with approximately 30 percent of all vehicles having an OOS brake violation". Properly working brakes are "important in order to reduce the potential for crashes".

- Axle weight violations were more common than GVW violations, with about two-thirds of vehicles cited with a weight violation being overweight on axles. On average, axle weight violations exceeded legal limits by 2,000 pounds.

Siekmann and Capps conclude that "it may not be safe to assume that a vehicle found to be overweight as part of this data collection effort is overweight on every load they haul, but it can be inferred that vehicles that tend to be overweight occasionally are lacking proper vehicle maintenance".

Indications of the magnitude of the overweight trucking problem have also been estimated through state-based surveys and data collection efforts. Straus and Semmens (2006, pp. 55-58) provide results from a survey of 25 states concerning their experiences with truck weight enforcement and overweight trucking. Responses indicate a wide-range of estimates (between 0.5 and 30 percent) as to the proportion of vehicle travel that is overweight in the surveyed states. Ramseyer *et al.* (2008, pp. 31, 49-53) conducted a survey of all 48 contiguous states concerning enforcement and compliance with 38 states providing responses (although not every question was answered by each respondent). The survey finds the following:

- Five of 12 responding states report that less than five percent of trucks weighed at weigh stations are overloaded; three of 12 responding states report overloaded rates at weigh stations between five and ten percent; two of 12 responding states report overloaded rates at weigh stations between ten and 15 percent; and two of 12 responding states report overloaded rates at weigh stations between 20 and 25 percent.

- 15 of 35 respondents indicated that weight compliance has increased due to implementing the Commercial Vehicle Information Exchange Window (CVIEW) or Commercial Vehicle Information Systems and Networks (CVISN); four indicated that compliance has not improved and 16 were undecided.

- 23 of 28 respondents indicated that intrastate trucks are overloaded more frequently than interstate trucks; two indicated that overweight trucks were equally distributed between intrastate and interstate trucks; and three indicated that interstate trucks are more frequently overloaded than intrastate.

- 14 of 26 respondents indicated that trucks with bulk material were most frequently overloaded; four indicated trucks with construction or commercial material were most frequently overloaded; and eight indicated that all types of trucks were equally likely to be overweight.

When considered together, despite some advances, the literature findings suggest that the lack of a comprehensive understanding of the magnitude of the overweight trucking problem in the United States—as identified by TRB some 30 years ago—remains today. Carson (2011, p. 38), concludes similarly in a recent compilation of significant TSW research, stating that there is a lack of reliable estimates on the extent of illegal TSW activity available in published research. This, combined with disparate enforcement practices across the United States, “challenges the ability to accurately assess the direct relationship between enforcement activities and truck size and weight compliance.” The literature that does exist (which is principally published prior to 2000) generally concludes that higher enforcement levels result in improved compliance. At fixed weigh scales on interstate highways, Carson reports a violation rate when enforcement is present of one percent, but a violation rate without enforcement of 15 percent. By-pass routes have violation rates of approximately 30 percent.

4.3 Effectiveness of On-Road Enforcement Methods

While uncertainty about the magnitude of overweight trucking remains, several studies have attempted to clarify the effectiveness of specific on-road enforcement methods. The use of fixed weigh scales and mobile enforcement patrols are the two most common methods of enforcing truck weights in the United States. More recently, states have complemented these methods with the application of numerous TSW enforcement technologies, including WIM devices and VWS (U.S. DOT 2000; TRB 2002; Cambridge Systematics 2006; Ramseyer *et al*. 2008; Cambridge Systematics 2009a; Cambridge Systematics 2009b; Carson 2011; OECD 2011). Carson (2011, p. 38) acknowledges the variety of TSW enforcement methods deployed in the United States and partially attributes the lack of a comprehensive understanding of the effectiveness of on-road enforcement methods to this disparity. Carson concludes that enforcement programs that combine fixed and mobile activities are “most effective in ensuring truck size and weight compliance," though these approaches have more recently been supplemented by greater implementation of technologies that broaden the temporal and geographic coverage of enforcement. The effectiveness of on-road enforcement efforts may be impeded by realities of the judicial system, where misdirected or ineffective penalties may exist and misunderstanding about the impacts of truck overloading leads to low prioritization in the court system.

This section chronologically presents findings about the effectiveness of on-road enforcement methods (i.e., fixed, mobile, WIM and VWS), in the context of their deployment within a TSW enforcement program. It also discusses how aspects of the judicial system (i.e., the level of sanctions and the use of relevant evidence) influences enforcement effectiveness.

4.3.1 Fixed Weigh Scales

- Taylor et al. (2000, pp. 237-238) suggest that low violation rates at weigh scales on primary highways is indicative of an effective enforcement program that deters overweight vehicles rather than an indication that enforcement is not required. The authors further suggest that accelerated infrastructure damage on secondary roads with less enforcement is an indication that increased enforcement is necessary. They reference studies performed by seven state agencies to conclude that overweight violation rates are around one percent for continuously operated (i.e., high enforcement level) weigh scales on U.S. interstates and between 12 and 34 percent for low enforcement level weigh scales (there is no definition for "low level").

  Taylor *et al.* (p. 239) also identify studies in Virginia and Idaho which found that up to 14 percent of truck traffic will use alternative routes to avoid weigh scales and that operators will travel up to 160 miles to avoid a weigh scale. Virginia has found that trucks will purposely group together to exceed the ramp capacity of a weigh scale, known as weigh scale running or plugging. Overweight trucks travel at the rear of these groups and bypass the scale when it has been temporarily closed. Virginia has found that more than 38 percent of trucks that were running by the scale were found to be overweight.

  Finally, Taylor *et al.* (p. 241) reference a model developed by researchers in Idaho which predicts that a continuously operated weigh scale with an area coverage of 160 miles would prevent approximately $46 million in pavement damage over the life of the pavement. Further, the authors indicate that a combination of fixed and mobile enforcement provides the best overall weight enforcement program.

- Strathman and Theisen (2002, pp. vii-viii) investigate the effectiveness of enforcing truck weights at a fixed weigh scale on Interstate 5 by collecting WIM data from three nearby sites: one site on I-5 and two sites on potential by-pass routes. Data were collected prior to, during, and after an extended scale closure. The study finds that trucks did not appear to avoid the scale; further, trucks did not divert to I-5 during the scale closure. The authors indicate that GVW on I-5 increased by 0.4 percent when the scale closed and decreased by 1.2 percent upon re-opening (these were statistically significant changes). The number of overweight vehicles (at a 95 percent confidence level) before closure was 2.27 percent, during closure was 3.67 percent (an increase of 61 percent), and after re-opening was 3.19 percent (a decrease of 13 percent). The authors found that five-axle combination trucks (including tractor semi-trailers and truck-trailer configurations) were "somewhat" more likely to exceed weight limits compared to other vehicle classes during this case study. Changes in weight for participants in the Green Light program (a transponder-based weigh station preclearance program) were minimal, suggesting that these operators were self-compliant or unwilling to risk losing their status and associated benefits.

Strathman and Theisen also suggest that: (1) relatively aggressive enforcement in Oregon reduces the impact of increases in truck weight due to a single scale being shut down; (2) weight enforcement at a single site on I-5 which is a major interstate and international corridor may have little impact on interstate truck weights; and (3) operators participating in truck programs that offer benefits to compliant trucks are less likely to operate heavier trucks.

- Han et al. (2012, p. 268) test adaptive WIM threshold algorithms that dynamically alter the weight threshold of advanced WIM sorting systems for inspection stations as they near capacity. The results show that fewer commercial vehicles enter the inspection station as it fills up and those that do are selected by a heavier weight threshold. Adaptive WIM threshold algorithms increase inspection station throughput without large capital investment, decrease the time inspection stations are closed, and remove a greater proportion of commercial vehicles with weight violations.

4.3.2 Mobile Enforcement

- Allen (2002, p. 180) states that visible mobile enforcement, when supported by portable computing equipment to enable real-time data input and extraction, "can deliver a significant level of behavioral change at a high benefit/cost ratio."

- The USDOT (2000, p. VII-7) indicates that trucks with more axles require more time to weigh. The report indicates that in Michigan, as an example, it takes two hours to weigh an 11-axle combination truck using portable scales.

- Straus and Semmens (2006, pp. 31-45, 55-58) provide results from a survey of 25 states concerning their experiences with truck weight enforcement and overweight trucking. The survey revealed the following insights:

  Mobile enforcement is useful for detecting and deterring overweight vehicle travel. Responses indicate a wide range of commitment to mobile enforcement programs in terms of budgets, person-hours assigned to this duty, and the number of vehicles weighed. On average, the budget for a state mobile enforcement unit was $3.7 million annually.

  Of the vehicles weighed using mobile enforcement the percentage of vehicles exceeding legal limits ranged from less than one percent to nearly 100 percent in the surveyed states. This range likely reflects the presence of targeting strategies. Of the overweight vehicles (where data are available), the average number of pounds overweight (on the whole vehicle) ranged between 2,000 and 10,000 lbs.

Evidence that trucks knowingly violate truck weight laws supports the notion of increasing resources on state roads during “after hours” times.

Of the various vehicle classes, class 9 vehicles (i.e., five-axle tractor semitrailers) have the highest rate of in-state overweight violations.

Honefanger et al. (2007, p. 2) evaluate procedures used for commercial vehicle size and weight enforcement in six European countries as part of an FHWA report. They find that there is a greater use of mobile enforcement activities than fixed roadside weigh scale facilities. The result is that fewer trucks are processed and inspection areas are physically constrained but there is more flexibility to respond to industry and more effective enforcement action.

4.3.3 WIM and VWS

- USDOT (2000, pp. VII-13 and VII-14) suggests that the use of WIM as a pre-screening device at fixed weigh scales “improve[s] the efficiency and effectiveness of operations.” The report also indicates that WIM devices require frequent maintenance and may not provide continuous operation. The report identifies the integrated use of WIM and photo imaging as a plausible option for issuing weight citations.

- TRB (2002, pp. 179-182) describes the use of automatic clearance systems (such as PrePass), which screen trucks on the road and allow non-violators to by-pass enforcement stops. These systems improve enforcement efficiency by enabling officers to target trucks more likely to be in violation, thereby reducing the cost of enforcement for the public sector and the enforcement-related costs incurred by carriers. The study discusses extended applications of automatic vehicle identification (AVI) technology, specifically in terms of permit enforcement, identification of repeat offenders, and automated on-board enforcement techniques. The study also identifies the need for databases and information systems to improve enforcement efficiency. Data needs include inspection histories and violations of size and weight, safety, and other truck regulations. “Data must be accessible in the field, comprehensive, and current.”

- Gu et al. (2004, p. 7) evaluate the use of WIM technology to reduce delay and improve enforcement at weigh scales through the use of micro-simulation software. The report evaluates weigh station design and operation by simulating different design strategies (one static scale, two static scales, ramp WIM scale, and mainline WIM scale), the impact of weight threshold used, WIM accuracy, and the percentage of trucks in the traffic stream equipped with transponders. The following conclusions are made: (1) the use of WIM technology improves the efficiency of weigh scale operation; (2) at least 30 percent of trucks should be equipped with a transponder (used to inform drivers if they need to enter the weigh scale) for mainline WIM operation to be effective; (3) due to the current level of transponder usage in the fleet (less than 30 percent), WIM scales are more effective on weigh scale ramps than on mainlines; (4) accuracy of WIM scales is “an important issue;” and (5) threshold levels are important to achieve a balance between weigh scale efficiency and effective enforcement.

- Santero et al. (2005, p. 15) analyzes the effects of overweight trucks on California highways and the potential benefit of implementing VWS. The author finds that 5.74 percent of pavement damage on the California highway network is directly associated with overweight trucks that represent fewer than 2.67 percent of the axles measured. Damage is calculated using ESALs that increase exponentially with vehicle weight. This results in overweight trucks being disproportionately large contributors to pavement damage. They conclude that if VWS were installed at the ten existing WIM sites which could provide the greatest benefit, the average pavement life saved across those sites would be 10.71 percent. The report assumes that "when installed, a VWS is 100 percent effective in deterring overweight vehicles" (p. 9) and that the WIM database is representative of the entire state network.

- URS (2005, pp. 2-3, 48-51) develop a statewide commercial vehicle compliance strategic plan for Minnesota. The report indicates that achieving truck weight compliance is complex and requires more than enforcement. The authors recommend establishing a network of virtual WIM stations to measure compliance and use Civil Weight Enforcement to help target enforcement efforts. Minnesota uses Civil Weight Enforcement (part of relevant evidence enforcement) to target repeat weight violators. This allows enforcement officers to use virtual WIM stations to identify habitual offenders and use this information to visit their premises and issue a civil citation (up to $10,000 fine).

  The study indicates that weight violators are rarely caught at fixed weigh scales and recommends installing VWS as a more effective approach. The study provides considerations for implementing VWS as follows:

  Roads with volumes greater than 500 vehicles per day
  Mainline roads in front of fixed weigh scales
  Primary, known by-pass routes for fixed weigh stations
  Ramp sorters at fixed weigh stations
  Trunk highways with substantial truck volumes
  Highways with high bulk commodity movements (*e.g.*, agriculture)
  Highways with one or more vulnerable bridge structures
  Newly rehabilitated roadways with significant truck volumes

  The study estimates and compares enforcement costs for fixed weigh scales and virtual WIM enforcement stations. They find that approximately 100 WIM sites could be built for the cost of one fixed scale site (this assumes $15 million for fixed site construction and $150,000 for a WIM site) and the annual operating costs for 100 WIM sites is about one-quarter of the annual cost of one fixed site.

- Cambridge Systematics (2006, p. D-11) outlines two specific benefits of VWS. First, these stations enable officers to target enforcement efforts on overweight vehicles, which reduces the amount of time used for weight enforcement at fixed weigh scales. Second, these stations are suitable for monitoring routes used by operators to by-pass fixed weigh scales, thereby targeting enforcement efforts and improving compliance. The report states that virtual weigh stations are "cost-effective" for size and weight enforcement and are "particularly effective" in urban areas where fixed weigh scales are uncommon.

- Clough Harbour and Associates LLP (2006, p. 19) perform a review of license plate recognition (LPR) technologies for the New York State Department of Transportation. They conclude that LPR "is not ready for, and in fact may never be best suited for mainline screening." The authors recommend that LPRs be installed as part of virtual WIM sites but used primarily as a data collection device. They also indicate that funds set aside for LPR screening would be better spent on regional transponder enrollment efforts as they "will always offer a safer more accurate method of commercial vehicle screening."

- Rooke et al. (2006, p. 38) identify six Use Cases for the EU's project REMOVE which seeks to provide a framework for WIM systems to reduce danger and damage caused by overweight vehicles. Use Cases are used to define the behavior of a system used for enforcement. They are listed below by level of technical difficulty or technical integration (beginning with the least difficult):

  Human selection is the traditional way of enforcement where officers use their experience to select potentially overloaded vehicles. No WIM devices are used in this application.

  Statistics and planning uses data collected from WIM systems to target enforcement activities temporally and increase the efficiency of enforcement resources. This also includes the measurement of damage to the infrastructure.

  Pre-selection relies on WIM systems to select potential offenders for further inspection by static scales. Pre-selection optimizes the ratio of citations given to the number of vehicles inspected. This application includes mobile screening and VWS technologies.

  Problem solving attempts to achieve compliance by solving the problems that underlie offenses. Problem solving can be applied two ways:

  - *Direct feedback* – a WIM system is used to warn passing vehicles if they are potentially overweight and directs them to off load locations.
  - *Company profiling* – involves collecting data and images from WIM systems of violators, using license plate numbers to identify the responsible company, and creating company profiles of their level of compliance. Based on their compliance level companies may be issued a warning letter or subject to a company visit.

  Direct enforcement uses the weight measurements from WIM systems for the direct weight enforcement of trucks similar to that of automatic speed enforcement. The threshold at which vehicles are found in violation is dependent on the accuracy of the WIM sensor and in this way "enforcement focuses on the more severe cases of overloading."

  Intelligence involves a collection of applications and the aggregation of data collected from each of them into intelligence for policing or enforcement application.

- Rodier *et al.* (2006, pp. 127-132) find that virtual vehicle compliance stations (i.e., VWS) can be located on potential weigh scale by-pass routes to effectively identify carriers that attempt to avoid weigh scales and to help enforcement officers target trucks with a higher probability of being overweight. Their review looks at the institutional and legal barriers of installing VWS for pre-screening and enforcement.

  The authors find the following regarding institutional barriers:

  Commercial vehicle operators are generally unsupportive of VWS due to confidentiality and operating cost concerns. Operators feel like these technologies collect private information about their operations and that there is potential to use this technology to increase government regulations or impose a weight-distance tax. To help alleviate this barrier the authors recommend consulting with industry early in the process of establishing VWS to create awareness about the benefits of these systems (*e.g.*, time and fuel savings for compliant trucks being able to by-pass scales).

  Public agencies are concerned about VWS due to the potentially high cost to implement, the lack of technical expertise to operate them, and distrust by enforcement officers about their accuracy. There are also concerns that VWS could reduce felony arrests, create a negative image of officers as "sneaky," deprive carriers of officer discretion, and face opposition by unions due to job security concerns. Some states or regions have existing pre-clearance programs and new VWS must interoperate with these programs. To overcome these barriers the authors recommend developing an incremental implementation strategy that begins with modest technologies, training programs, and staff requirements and ensuring proper communication and coordination between different government agencies and personnel.

  The authors find the following regarding legal constraints:

  There are concerns from commercial vehicles operators that certain constitutional rights and protections may apply to automated enforcement programs; however, the authors find that VWS do not violate constitutional rights and freedoms.

  Amendment to state law is often required to use VWS for automated enforcement and may be required for non-voluntary pre-screening applications (e.g., amendments that ensure business confidentiality). However, state laws may not require amendment for voluntary pre-screening applications.

  The report discusses program design elements to consider when implementing a VWS as follows:

  Vehicle owner versus driver citations: If VWS are used for enforcement (as opposed to screening), issuing a citation to the registered vehicle owner based on the license plate (as opposed to issuing a citation to the driver) reduces the enforcement effort, limits the infraction to a civil penalty, and can be less effective in preventing future violations. If citations are issued to the driver (as opposed to the registered vehicle owner), the effort to match the identity of the driver to the photo taken at the VWS becomes onerous and often inconclusive; however, the infraction can become a criminal offense which serves as a much stronger deterrent for future violations.

Fixed versus mobile cameras: Compared to mobile manned cameras, fixed unmanned camera locations are usually less costly to operate, can be operated 24 hours per day, and have a smaller footprint which may allow them to operate in more locations. However, mobile manned cameras provide better geographic coverage.

Placement of VWS: The authors recommend installing VWS only on routes with a significant violation problem or routes that could be used to by-pass a weigh station.

Enforcement threshold: If VWS are used for enforcement, states should set a threshold that is higher than the legal weight but below which they do not issue tickets to account for potential inaccuracies of weighing equipment.

Responsibility and authority for administering and operating VWS: Legal challenges can arise if the state leases the video monitoring equipment and services necessary to operate the program from a vendor. Citations can be dismissed in court if the vendor is paid by the number of tickets issued, if vendors are allowed to select enforcement locations, or review tickets.

The researchers suggest the following steps to address stakeholder barriers to implementation for using VWS for screening and enforcement:

"Start with smaller, less costly, and less controversial programs.

Establish multiagency working groups early in the process.

Include the judiciary in working groups if automated enforcement is being considered.

Involve the Commercial Vehicle Operations (CVO) industry early in the planning and implementation process through advisory groups.

Conduct targeted educational outreach efforts for agencies and the CVO industry.

Document and communicate the costs and benefits of the program."

- Honefanger *et al.* (2007, pp. 2-5, 39) evaluate technologies and procedures used for commercial vehicle size and weight enforcement in six European countries as part of an FHWA report. They find the following:

  Two of the six countries use technology for vehicle size enforcement that includes an automated profile measuring device and a gantry laser scanner. For speeds less than 10 km/h these systems provide an accurate dimensional picture suitable for legal enforcement. In high-speed applications they can be used for pre-selection.

  Bridge WIM systems have been successfully implemented in Slovenia, are undergoing tests in France, and have sparked interest in other EU countries. Slovenia has found most success with WIM systems on short, stiff bridge structures.

- Piezoquartz or piezoceramic WIM sensors have been consistently used for roadway applications in the European countries who took part in the scan.
- The accuracy of WIM systems is sufficient for pre-selection but not for direct automated enforcement. The Netherlands credits their pre-selection process with increasing officer efficiency from 40 percent to 80 percent (citations issued relative to vehicles stopped). Their pre-selection system includes piezoquartz WIM sensors in the two right-most lanes, two cameras on each side of the road to capture vehicle images, a camera above each lane to capture license plate numbers, and electronic loops and cameras in the third lane to capture bypassing vehicles. The Netherlands also utilizes the data collected from their pre-selection system to direct advisory notices of non-compliance to carriers consistently in violation of TSW regulations. These advisory notices are thought to be more effective than roadside inspections because a "single contact can reach companywide rather than a single driver." Both the Netherlands and France are researching the accuracy of multiple-sensor WIM systems for direct enforcement. While it was not observed as part of the study, the United Kingdom, Belgium, and Germany are reportedly already using low-speed WIM systems for direct enforcement.

The report identifies seven specific implementation opportunities from European countries that would have the greatest potential benefit for commercial motor vehicle (CMV) enforcement in the U.S. Four of these implementation opportunities involve enforcement technologies.

- *Slovenia bridge WIM*: This involves weight-detection instrumentation installed under the bridge deck without disrupting traffic flow on the bridge. Once bridge deck substructures have been instrumented they can be easily removed and installed elsewhere on a rotational basis. The selection of a suitable bridge and the calibration of the B-WIM sensors may involve a high level of expertise.
- *Swiss heavy goods vehicle control facility*: This facility pre-selects CMVs using a HS-WIM combined with video technology. Potential violators are intercepted for static weighing while an overhead gantry fitted with laser scanners measures CMV width and height simultaneously.
- *Prescreening for mobile enforcement*: While the U.S. uses this approach to varying degrees there is a need for a comparative analysis with European state of practice.
- *Applying WIM for direct enforcement*: French officials are leading the way to overcome the institutional barriers that prohibit the use of low-speed WIM technology for direct enforcement while the Dutch are focused on acceptance of high-speed WIM technology.

Finally, the report notes that benefits from enforcement technologies currently used are not yet "precisely quantified." The most common quantified benefit relates to enforcement efficiency calculated as the number of overweight citations per total trucks inspected. Further benefits may be realized by the implementation of high-speed WIM systems for direct truck weight enforcement, although, as of 2007, both France and the Netherlands indicate that such systems are five to 20 years in the future.

- Jacob and van Loo (2008, p. 33) conclude that the two technologies which are able to fulfill the requirements for enforcement in the traffic flow are the multi-sensor (MS-) WIM and the bridge (B-) WIM. The requirements for WIM accuracy, defined as class A(5) of the COST323 Specification, are ± 5 percent for gross weights, ± 8 percent for axle group loads, and ± 10 percent for single axle loads with a confidence level greater than 96 percent. The use of these technologies for vehicle weight enforcement depends on the legal certification of high speed (HS-) WIM systems.

    MS-WIM systems can only achieve class A(5) tolerances if they are set up in arrays of eight to 16 sensors. This requires highly efficient algorithms, accurate and reliable strip sensors, powerful calibration procedures, and detailed quality assurance.

    Bridge-WIM (B-WIM) systems have been shown to achieve class A(5) tolerances on some types of bridges for GVW and axle group loads. The benefits of B-WIMs are that they are almost undetectable by drivers and do not require lane closures for installation and maintenance.

- Jones (2008, p. 265) investigates the effectiveness of combining high-speed WIM sensors with overhead mounted automatic number plate recognition (ANPR) cameras to better identify vehicles in violation of TSW regulations in the United Kingdom. This system is connected to an ANPR database containing individual permitted maximum axle and gross weight limits for all U.K. registered trucks, buses, and coaches. This connection enables the system to classify vehicle configurations that are difficult for WIM sensors to classify and has had an "enormous benefit." The weight threshold for potential violators was set at eight percent overweight by axle or GVW. This results in an average of 240 overweight alerts per day of which six percent are inspected due to staffing limitations. The research finds a 90 percent overload prohibition issue rate.

- Marchadour and Jacob (2008, pp. 268-271) describe the development and implementation of a WIM network for enforcement in France. They tested low-speed WIMs (maximum vehicle speed of 4.5 km/h) installed on a concrete slab (36 m by 4.5 m) and found that they could be used for direct enforcement and could be installed, removed, and deployed at different sites. They also tested high-speed WIMs (maximum speed not specified) and found that they were inadequate for direct enforcement but useful for screening potentially overweight trucks.

    The authors develop a national WIM network with three objectives:

    Pre-select and identify overloaded or speeding trucks prior to a weigh scale station

    Identify frequently overloaded carriers

    Gather statistical traffic data to determine the most overloaded road sections and time periods

    To achieve these objectives, the researchers installed video-WIMs at selected sites upstream of a weigh scale which collected the following information:

Vehicle classification (22 categories)
Axle loads and GVW
Speed and length
License plate information

These systems identify trucks that are potentially overloaded or speeding and send the data to a central server and to officers at the downstream weigh station. If officers are on duty, they use the data to select vehicles to inspect. These data are centrally stored and analyzed to identify frequently speeding or overloaded carriers.

- Ramseyer *et al.* (2008, pp. 41-45) conduct a survey of all 48 contiguous states concerning enforcement and compliance with 38 states providing responses (although not every question was answered by each respondent). The survey finds the following:

  31 of 38 respondents indicated they have WIM systems for truck weight enforcement.
  16 of 29 respondents indicated they use virtual enforcement (which normally involves a WIM and an image capture system); 13 do not, and nine did not respond.
  21 of 26 respondents indicated they use an electronic by-pass system (which normally involves a WIM and other vehicle identification technologies placed in advance of a fixed weigh scale); five do not and 12 did not respond.

- Stanczyk et al. (2008, p. 290) test a VWS in France for accuracy. The authors recorded an accuracy of B(10) according to COST323 specification which is acceptable for pre-screening. They report that 96 percent of pre-selected vehicles were overloaded.

- Cambridge Systematics (2009a, p. 2-1 to 2-11) interviews nine states that are at the forefront of the deployment of roadside technologies. The report indicates that data from traffic monitoring WIM systems can be used for the informed placement of future WIM systems to aid in enforcement activities and to identify the most productive locations, days, and times for enforcement activities. This can be accomplished by quantifying factors temporally such as truck traffic volume and the frequency of overweight trucks. Additionally, despite deployment of technology for pre-selection, enforcement activities are still limited to the number of enforcement personnel on duty at any given time in a region because citations can only be issued once a human weighs a truck.

  Specifically, the report describes the following standard applications of roadside technologies:

  Traffic monitoring WIM systems are primarily used for planning activities but can help target enforcement resources.
  Mobile screening at WIM sites require that the WIM system has wireless connectivity so that an enforcement officer can physically monitor the real-time WIM data on a laptop from the roadside. The officer must be close enough to the WIM site to visually match the CMV with its WIM data. Potential violators are intercepted for further inspection at a stationary weigh station or a mobile weigh station.
  VWS consist of a mainline WIM system, high-speed communication, and a camera system that eliminates the need for an officer to be on site to match the CMV with

its WIM data. VWS can be enhanced with optical technologies that have AVI capabilities that may be integrated with additional information from safety and vehicle databases.

Fixed site-based mainline weight screening relies on a mainline WIM system to screen CMVs traveling at highway speeds for weight compliance as they approach a weigh station. Potential violators are signaled to pull-in to the station for further inspection. When coupled with an electronic screening or bypass system, CMVs may be verified for bypass eligibility based on their weight, safety, and credential information.

Ramp sorting utilizes a WIM system on weigh station ramps to screen CMVs by weight as they approach weigh stations travelling at low speeds. Once CMVs are weighed they are signaled to either proceed to the static weigh scale or to return to the highway via a bypass lane. WIM sensor accuracy is higher for ramp sorting applications than mainline WIMs due to lower travel speeds.

The report provides the following findings concerning WIM systems:

The costs of WIM systems (per lane) based on actual implementation experience in the U.S. is as follows: piezoelectric—$16,000; quartz piezoelectric—$29,000; bending plate—$40,000; and single load cell—$87,500. The more expensive systems are found to be more intrusive to the pavement structure but have an increased service life. The accuracy of the piezoelectric WIM is less than the other technology devices at 85 percent compared to 95 percent.

A typical weigh station can cost anywhere from $12 million to $300 million depending on the land purchase requirement. Alternatively, based on fund requests from the FMCSA from 2006 to 2008, VWSs cost from $300,000 to $1,400,000 depending on additional enhancements like AVI technologies. One state indicated that the cost to upgrade an existing WIM site with mobile screening capabilities was marginal. Many states are choosing to deploy VWS and mobile screening due to the "increased scope of enforcement activities at less cost and staff than are required by weigh stations operations".

Motor carriers express concerns about data generated from roadside enforcement activities. The concerns include data retention time, usage beyond tangible goals in the public's interest, and data being leaked to their competitors

- In a 2009 state of the practice report for the FHWA, Cambridge Systematics (2009b, p. 2-6) states that the use of WIM technology for direct enforcement activities is "not a target of the FHWA or state Departments of Transportation (DOTs) or law enforcement agencies." Rather WIM technology is commonly used for the pre-selection of vehicles that have a higher risk of being non-compliant, and effectively reduces the amount of compliant trucks that are inspected. Further, they have been developed to virtually screen vehicles in real-time at inspection stations that are unstaffed.

  The report (p. 3-3) discusses the recent increase in WIM use on inspection station approach ramps in the U.S. This configuration takes advantage of a commercial vehicle's reduced speed to obtain more accurate axle weights. Inspection officers set the weight thresholds and vehicles that exceed that threshold must stop for further inspection. Four of the nine states that participated in the study have five or more of these weigh stations.

In particular, the report identifies Washington State's Commercial-vehicle Roadside Information Sorting System (CRISS) as an example of how high-speed WIMs (HS-WIM) are utilized for fixed weigh station operations. Washington State has installed WIM sensors coupled with cameras at 14 of its weigh stations that provide coverage for over 80 percent of the commercial vehicle fleet. The CRISS software provides inspection officers with an image of each commercial vehicle along with its weight information and an algorithm determines if there are potential axle weight violations.

Finally, the report (p. 4-3) discusses the use of WIM systems for mobile screening as a form of pre-selection for enforcement. Inspection officers at the roadside receive real-time vehicle weight information wirelessly from a WIM system located upstream and use it to intercept potentially overweight trucks for further inspection. This type of enforcement pre-selection can be achieved at a relatively low cost as any WIM system can be upgraded to have wireless connectivity. Mobile screening sites require WIM sensors, a roadside processor, wireless connectivity, a data receiver in the patrol car, and a laptop with the appropriate software. The inspection officer must be near enough to the WIM site to be able to visually identify vehicles as they pass over the sensors. The authors find that states consider mobile screening to be "well worth the costs" particularly when existing WIM systems are upgraded.

Similar to mobile screening, VWS rely on WIM systems to provide weight information of vehicles but they are enhanced by a digital imaging system to identify potential violators. This reduces the need for permanent on-site staff as potential violators can be identified by officers remotely from multiple images of the vehicle. Indiana estimates the cost to retrofit existing WIM sites to VWS to be approximately $30,000. The digital imaging system can be further enhanced with optical character recognition (OCR) software to relieve the need for manual vehicle identification by providing a license plate number. This is particularly important in areas with high truck traffic volume.

- Cambridge Systematics (2009c, p. ES-19, 3-7) lists the following benefits of license plate readers and other AVI technologies: (1) enable officers to target likely offenders; (2) improve data collection; and (3) enable timely access to safety, credentials, and criminal records.

  The report also indicates (p. 3-7) that on-board scales can be used to monitor truck weight. Information can be extracted from the devices for enforcement purposes by directly plugging into the device or via a wireless connection. The devices help expedite the inspection process at weigh scales thereby reducing enforcement costs. The accuracy of these devices is "still questionable." In addition to weight, on-board equipment can also be used to monitor brake and tire conditions, lighting, steering, suspension, exhaust, and horn operation.

- Hahn and Pansare (2009, pp. xiv-xvii) provide detail on Maryland's implementation of VWS, which are intended to augment current enforcement activities at fixed facilities and mobile patrols. In Maryland, the goals of the VWS pilot project are: (1) to provide a platform for helping law enforcement personnel target enforcement activities; (2) to develop a "stable, accurate, and standard platform for rapid deployment at other statewide locations"; (3) to determine, from a research perspective, whether a relationship between weight and safety exists; and (4) to provide recommendations and guidelines in expanded deployment of the VWS concept.

  The pilot project deployment involved two phases of tests. The first phase involved a predefined set of vehicles and confirmed that the VWS met relevant technical requirements. The second phase involved a set of on-road vehicles and also confirmed that the VWS met technical requirements (except for the gross weight requirement which was "not met completely").

  Data collected by the VWS provide "valuable clues to focus their inspection efforts during time periods that suggest more over weight and/or over height violations." No relationship between weight and safety violations was observed. The study concluded that the VWS "improved the effectiveness of [commercial motor vehicle] selection methods significantly over a traditional method relying on random selection."

  [A follow up discussion with Maryland State Police and Maryland State Highway Administration in August 2013 revealed that current VWS and future VWS (22 total VWS stations by 2017) will incorporate Drivewyze Inc.'s PreClear service. Drivewyze is an "inspection site bypass system which adds transponder-like functionality to tablet computers and smart phones, and enables enforcement officers to electronically pre-screen trucks traveling at highway speeds (Transport Topics 2013, p. 15)."]

- Hanson et al. (2010, p. 8) evaluate the percent of commercial vehicles being required to report to an inspection station in Nova Scotia, Canada before and after the installation of an advanced WIM sorting system was implemented in 2007. They found that after implementation the inspection station required 23 percent of commercial vehicles to stop versus the 60 to 70 percent that were required to stop previously. There was also a 27 percent decline in citations from 2005 to 2007 after implementation.

  The authors also document (p. 10) the use of a VWS in Newfoundland and Labrador, Canada for follow-up enforcement of commercial vehicle violations. The VWS system includes a quartz WIM sensor and multiple cameras that are triggered by inductive loops. The cameras are configured to only collect images of the violating commercial vehicles that are identified in real-time by the WIM device. The data are filtered and used to notify carriers with "non-compliance tendencies" that they may be subject to further enforcement.

- Kwon et al. (2010, p. 6) test a high-speed WIM (HS-WIM) system in Korea that includes a "wandering sensor" to detect the relative position of the driving vehicle in the lane and to increase the accuracy of vehicle classification for lift axle configurations. This system is found to be effective at detecting five-axle trucks with a lift-up axle. The HS-WIM sensor accuracy is tested following European COST323 WIM specification test conditions. The accuracy of the system is within 5 percent for gross weight error but receives a COST323 accuracy of class B+(7) due to the error range of the axle group performance.

- Australia's National Transport Commission (2011b, p. vi) investigates the deployment of on-board mass technology as a means of supporting truck weight enforcement in Australia. The Commission evaluates three options, including "business as usual," mandatory installation, and voluntary installation. They conclude that the use of on-board mass systems should be "on a predominantly voluntary basis" by carriers as a means of meeting weight compliance regulations. Mandating the use of a specific technology restricts carriers in how they may develop cost effective weight compliance management systems. However, it is understood that repeat violators may need more prescriptive measures.

- Lee and Chow (2011, pp. 92, 99, 102) develop a simulation model to estimate the effectiveness of e-screening (i.e., screening trucks upstream of an inspection station using WIM) and the effect of transponder adoption. The researchers apply the model to a small weigh scale station in Canada (Port Mann, British Columbia) with a short queuing area and high truck volumes. Transponders are used to automatically send the credentials of the truck and driver to the weigh station as the truck approaches the weigh scale. This information helps the enforcement officers determine if the truck should be inspected for purposes other than weight. The authors find that e-screening improves overweight enforcement and that these improvements are enhanced as transponder adoption increases. The model shows an enforcement rate of 99.0 percent when 75 percent of the trucks have transponders and 49.9 percent when none of the trucks have transponders. Overall the study finds that at least 20 percent of the trucks passing the station must have transponders to show any type of enforcement benefit.

- OECD (2011, pp. 290-292) indicates that the WIM technology for direct truck weight enforcement remains an emerging practice in most countries today. That is, an overweight measurement recorded dynamically at high-speed by a WIM device is not normally used as the sole evidence of an overweight violation. Nevertheless, WIM applications for enforcement include:

  the use of WIM as a pre-screening tool to identify and direct vehicles likely to be overweight to a traditional static weigh scale site for weight validation;

  WIM monitoring to identify times and places in which overloading may be more problematic, so that enforcement activities can be better targeted; and

  WIM monitoring of bypass routes to support other enforcement activity.

  The report also comments on several other truck weight enforcement technologies:

  On-board weighing systems have been used by carriers for certain industry sectors as a tool to help avoid inadvertent overloading. In Australia, recent findings indicate that the accuracy levels and tamper-resistant capabilities of these technologies are now sufficient for regulatory enforcement applications.

The Australian Intelligent Access Program uses satellite-based vehicle position and tracking technologies to ensure that trucks adhere to relevant highway network restrictions (which are defined based on TSW limits).

Data capture, storage, analysis and reporting technologies will enable "more effective compliance and enforcement" through better targeting of high-risk drivers and operators and automated enforcement of violations without human intervention.

- CDM Smith (2012, p. 4) reviews multi-state weigh station pre-clearance systems for Minnesota. Trucks that are part of pre-clearance programs are fitted with transponders that communicate their size, weight, and identification to roadside readers. Additionally, their unique identification is matched against a database that contains information on the recent safety and credentials of the carrier and truck. If the data indicates compliance then the truck is given authority to by-pass the scale. The authors identify two multi-state pre-clearance systems available to state DOTs and note that two states have developed their own systems. However, many states are moving towards VWS as they do not require transponders in trucks for pre-clearance. The two multi-state pre-clearance systems are described briefly below:

  PrePass® has adopted the Inspection Selection System (ISS) developed by the FMCSA as its primary criteria for safety clearance. Many PrePass® systems do not include mainline WIM sensors. PrePass® operates in 31 states with over 305 sites.

  NORPASS operates in eight states but was giving consideration to migrate their system to PrePass®.

- Hitchcock et al. (2012, p. 59) test the SiWIM system, a bridge WIM system developed by CESTEL, for enforcement application in Alabama. They find that: (1) SiWIM systems can be installed in one day and calibrated in an additional day after completing ten acceptable calibration runs in each lane; and (2) a maximum of two lanes on a bridge and steady travel velocity improves successful vehicle capture (rigid short span bridges are preferred).

- Jones (2012, pp. 4-6) describes a technology used in New South Wales in Australia called Truckscan. This technology pre-screens trucks using WIM and license plate readers to identify high risk trucks that should be stopped for inspection and low risk trucks that can by-pass an enforcement facility. Technologies such as WIM and others are used to determine the vehicle's weight (axle and gross), height, length, classification, and speed. A video camera captures a vehicle's license plate which is used to determine the vehicle's status in a national database, its registration number, and historical information (e.g., citations). Truckscan considers 36 criteria in establishing the risk of a truck and uses an algorithm to compute a risk score. The time to compute the risk is about six seconds.

- McBride and Kirby (2012, p. 8) indicate that transport operators who elect to voluntarily share their electronic vehicle data may be held to alternative enforcement intervention. This may include authorization to by-pass active weigh sites with a view to increasing productivity and encourage compliance. Electronic vehicle data could include position, road user charges, engine management, and driver identification data.

The authors also identify (p. 39) three high-level concepts of operation that utilize strategic electronic monitoring (SEM): (1) direct automated enforcement, (2) automated inspection with targeted intelligence driven enforcement, and (3) electronic screening with low-speed/static inspection. They indicate direct automated enforcement as the most direct and productive high-level concept that utilizes SEM. Direct automated enforcement relies on road side technology to detect vehicles operating outside a specified range and automatically notifies the operator/driver/owner with an infringement notice requiring no police enforcement resources. The implementation of such a concept requires significant political will as it will most likely occur simultaneously with changes to current governing laws for heavy commercial vehicles.

The authors recommend (p. 57) SEM that consists of these primary high-speed technologies:

- An evidential grade high-speed WIM system that meets the updated international WIM Specification standard OIMLR134.
- 3D cameras equipped with infra-red and color capture that utilize image processing software to accurately calculate vehicle characteristics including speed, following distance, vehicle classification (height, width, length), among others.
- 2D cameras for side views to confirm axle groups. When coupled with automated number plate recognition systems, these systems can identify vehicles that avoid inspection stations.

4.3.4 Enforcement Effectiveness and the Judicial System

In addition to the foregoing assessments of on-road enforcement methods, the literature discusses how two aspects of the judicial system—the severity of sanctions and the use of relevant evidence—influence enforcement effectiveness.

The severity of sanctions for overweight trucking has been found to influence the effectiveness of truck weight enforcement programs and offers an alternative strategy to increasing on-road enforcement intensity. TRB (1990, pp. 135, 143) contends that to be "effective," the enforcement of weight regulations requires that they be uniform, relatively simple to comprehend and apply, and that penalties are sufficiently severe so as to deter non-compliance. The report also observes that "because of the economic incentives for illegal overloading, honest truckers are at a disadvantage in competing for work with those who violate the law." From this perspective, any non-compliance would appear to be inappropriate—not so much because of its economic effect on infrastructure as from its implications for "the even playing field." Similarly, Cambridge Systematics (2009c, p. ES-10) indicates that current enforcement levels and low fines provide an "incentive for noncompliance." This conclusion is based on public outreach conducted as part of Wisconsin's TSW study.

Strathman (2001, p. 7) conducts a statistical analysis to develop linear regression models that relate enforcement intensity, fines, truck volume, and value per ton. The author finds that increasing enforcement or increasing fines have about the same effect in deterring overweight vehicles; however, the effect of enforcement is primarily attributed to mobile patrols. The author concludes that the most cost-effective way to reduce overweight vehicles is to increase fines since this has about the same effect as increasing enforcement levels but without the extra costs of enforcement.

Relevant evidence laws have seen limited use in the United States, though they are recognized as one option to improve TSW enforcement program effectiveness. Citing Minnesota as an example, the USDOT (2000, p. VII-12) indicates that bills of lading, weight tickets, and other relevant documents are used as legal evidence to establish an overweight violation. Enforcement occurs through an audit of shipper or freight forwarder files, with legal action possible against the driver, shipper, owner, or lessee. The program is built around the law that all receiving sites in Minnesota must retain weight bills and allow access to enforcement officers within 14 days of when the shipment was received (Cambridge Systematics 2009b, pp. 4-6). While the use of relevant evidence laws has been successful in Minnesota, pilot programs in the 1990s in four other states (Iowa, Louisiana, Mississippi, and Montana) were unsuccessful because of industry opposition to the required legislative support. The report identifies the administrative system used in Georgia to process weight citations as an alternative to the court process (USDOT 2000, p. VII-12).

4.4 Regulatory Changes and the Effectiveness of TSW Enforcement

The literature identifies a relationship between changes in TSW regulations and the effectiveness of TSW enforcement. TRB (2002, pp. 171, 173-174) suggests that a lack of sufficient enforcement impedes the effectiveness of TSW regulatory reform. Regulatory complexity or the introduction of trucks that may be easier to overload are examples of enforceability problems that may occur due to reforms. Similar problems may result from permit programs or exceptions that continue to grow and become more complex, particularly since data about the number of legal permitted loads operating in excess of 80,000 lbs. and the distance these loads travel are limited.

In two separate state-based TSW studies (Wisconsin and Minnesota), Cambridge Systematics (2006, p. 20) (2009c, p. ES-17) suggests that changes in TSW laws may necessitate additional enforcement resources (particularly inspection personnel) and that the complexity of TSW laws “complicate compliance”. Similarly, Carson (2011, p. 38) asserts that TSW regulations “should be uniform in their scope and relatively simple to comprehend, apply, and enforce.” Regulations that are too complex or which contain numerous exceptions lead to lower levels of enforcement and prosecution.

Woodrooffe et al. (2010, p. 30) also identify enforcement resource implications of changes in TSW laws. In a review of TSW regulation in Canada, the authors indicate that certain provinces had to replace their platform scales to accommodate tridem axle groups (with a 3.66 m spread), which were allowed nationwide for the first time after the Memorandum of Understanding on Vehicle Weights and Dimensions was implemented in Canada in 1989.

Pilot programs offer a potential opportunity to examine the relationship between regulatory change and enforcement effectiveness. The FHWA (2012a, pp. 21-22) investigates enforcement levels and overweight axles as a potential contributor to truck crashes as part of the Vermont pilot program. This program saw an increase in TSW limits on Vermont’s interstate highways for a one-year period, including allowance of a 6-axle tractor semitrailer limited to 99,000 lbs. GVW. The report indicates that, on average in Vermont, three percent of single axles exceed the 20,000-lb. limit and 13 percent of tandem axles exceed the 36,000-lb. limit in effect during the pilot program. The overweight observations may or may not involve pilot vehicles or vehicles operating under permit. In addition, an analysis of crash data reveals that approximately half the carriers involved in the pilot program were involved in crashes during the program, though these crashes may not have involved pilot program trucks.

In a related 6-month report on the Maine and Vermont pilot program, the FHWA (2012b, pp. 2-3) describes preliminary findings of the program with a focus on bridge and pavement impacts. The program allows for gross vehicle and axle weights on interstate highways beyond normal federal limits. In Maine, the program enables operation of six-axle tractor semitrailers up to 100,000 lbs. and tandem axle weights up to 46,000 lbs. for certain commodities. In Vermont, the program enables operation of six-axle tractor semitrailers up to 99,000 lbs. and tandem axle weights up to 39,600 lbs. (inclusive of a 10 percent weight tolerance). The report does not make direct reference to enforcement issues, but does mention the need for increased monitoring of bridges using WIM devices. Regarding pavements, the increased vehicle loadings would cause additional pavement damage which could be limited through industry co-operation and increased enforcement; no details are provided as to the extent of benefit that may be gained by industry co-operation and increased enforcement. Conclusive findings are expected after the full implementation of the program.

ADDENDUM – ADOPTED AUSTRALIA COMPLIANCE

This appendix provides a chronological, document-by-document summary of literature related to alternative approaches for achieving compliance—principally those adopted in Australia.

- Johnstone (2002, pp. 24, 25, 31) notes that road transport regulation, including TSW regulation, has historically necessitated ensuring regulatory compliance with prescriptive requirements. On-road enforcement directed at drivers and operators has been the primary instrument used to achieve compliance with these regulations. This approach has been criticized because it ignores the responsibility of other parties within the logistics supply chain for a non-compliant event and it has applied a penalty structure inadequate for deterring non-compliant behavior. In Australia, this criticism has led to the adoption of the chain of responsibility principle in which all parties within the trucking contractual chain have some duty to ensure compliance (including compliance with TSW regulations). From a legal perspective, this duty must be established through a causal nexus between each party's activities and a non-compliant event.

- McIntyre (2002, pp. 53-55, 60-64) describes the (Australia) National Road Transport Commission's (NRTC) approach to enhancing a compliance culture. The author asserts that a "nationally consistent, well-targeted approach to enforcement is an important component of the Commission's strategic framework for compliance reforms." However, conventional (sanctions-based) enforcement is considered only one of a number of additional strategies needed to create a sustainable compliance culture for the trucking industry. Additional strategies, include:

  Privileges and incentives-based strategies such as accreditation-based schemes;
  Training of enforcement officers and industry;
  Education and communication strategies;
  Monitoring of enforcement effectiveness; and
  Ongoing research to ensure programs adjust to technological, societal, and legal developments.

  A combination of approaches enables a more proactive (rather than reactive) means of achieving compliance. The author cites the following reasons why a reactive, enforcement-oriented response is insufficient:

  "The effectiveness of enforcement-based strategies to modify road user behavior is dependent on there being a perception that there is a real possibility that breaches will be detected. However, there are simply not enough policing resources to cover the whole road network, and the chance of apprehension at any one time is low.
  Fines, no matter how high, will not have a sufficiently deterrent effect when the chance of detection is slight but the potential profits from offending are high.

> Targeting only the driver and owner of heavy vehicles (the 'soft' enforcement options) will not deter the many 'off-road' parties who play a significant role in breaching the road laws."

Australia's NRTC (as of 2002) proposed a reformed legislative approach to address these issues. Specifically, the legislation incorporates the chain of responsibility principle (including the parties involved in consigning, loading, carrying, driving, receiving, and packing) and the requisite enforcement powers to support it (such as compliance audits and the legal acceptability of various types of evidence). In addition, it provides a risk-based categorization of offences to account for varying severity and to enable distinctions between unintentional offences and those committed for commercial gain, between individuals and corporate bodies, and between first time and habitual offenders. The reforms also adjusted penalty structures.

- McKeachie and McCrae (2002, p. 116) describe the various elements of the "enforcement pyramid," which depicts a series of progressively more aggressive enforcement tools (moving from bottom to top), all of which are directed at achieving regulatory compliance (though not applicable only to the trucking industry). Starting at the base, the pyramid includes: persuasion and education, administrative penalties, civil penalties, criminal penalties, suspension, and revocation.

- Leyden et al. (2004, pp. 3-9) describe Australian approaches to heavy vehicle accreditation and compliance. The authors recall that in 1997 the Australian Transport Ministers approved a voluntary accreditation system (National Heavy Vehicle Accreditation Scheme) where operators who apply for accreditation must have systems and procedures in place that will provide evidence of compliance. Accredited operators are subject to fewer roadside inspections and are instead subject to an ongoing audit regimen to ensure compliance is being maintained (p. 3). The authors state that adopting accreditation systems and providing various benefits to accredited operators (e.g., higher weight limits, broader access to certain road networks) can serve as a powerful mechanism for compliance and also increase the efforts of regulators and the documentation they must keep to respond to legal challenges by operators who have been denied accreditation. They also briefly describe the chain of responsibility concept and explain that any entity that exercises control over any of the following activities are subject to joint and several liability for overloading trucks:

  Consigning
  Loading
  Carrying
  Driving
  Receiving

  Under this enforcement and compliance approach, violators (*e.g.,* consignors, carriers, receivers, etc.) must demonstrate that they took reasonable steps to avoid breaching weight limits or that they neither knew nor reasonably ought to have known of the breach. This encourages the installation of documentation systems to achieve and demonstrate compliance. The law also allows senior officers of a company (*e.g.,* director, manager) to be punished for committing a road law offence or encouraging a truck to operate overweight.

Australia created three categories of weight violations:

Minor (up to five percent above legal limit)
Substantial (up to 20 percent above legal limit)
Severe (above 20 percent of the legal limit)

Australia also created a hierarchy of sanctions that provided flexibility and options for disciplining violators. This recognized that conventional fines may not be a deterrent for all parties in a logistics chain. Following is the hierarchy of sanctions in order from least punitive to most, where the first three are administrative sanctions and penalties and the remaining are court sanctions and penalties:

Improvement notice
Formal warning
Infringement notice
Fine
Commercial benefits penalty
Supervisory intervention orders
Orders affecting licenses and registration
Prohibition orders

Australian law also allows the courts to issue a compensation order to an offender which compensates the road authority for loss or damage to any road infrastructure caused by the offense.

The authors find that enforcing the chain of responsibility has led to significant improvements in documenting heavy loads, and that this documentation helps audit the evidence produced by accredited carriers. Australia is also finding that more shippers and receivers are including a requirement to be accredited into their service contracts to help mitigate their risk under the chain of responsibility.

- Germanchev and Bruzsa (2006, pp. 2-10) describe a hybrid testing method to prove the compliance of heavy vehicles. Based on experience with Performance Based Standards in Australia, the authors find that the best method to assess the performance of trucks is a hybrid method consisting of simulation and field testing. This approach inputs the specifications of truck configurations into a simulation model to predict how the vehicle will operate and behave under different conditions. The truck configuration is then tested in a private testing facility which replicates the driving conditions of the model. Field measurements are recorded and used to calibrate the model. Once calibrated, the model is used to determine the predicted performance of the truck configuration on different types of roadways in Australia to determine where this truck will be permitted to operate. The authors find that the combination of simulation and field testing is a robust and accurate approach to predict the actual performance of a vehicle configuration under different conditions.

- Australia's National Transport Commission (2007, pp. 1, 4) provides a report outlining the National Heavy Vehicle Enforcement Strategy, aimed at promoting consistent, effective and efficient enforcement in heavy vehicle transport law in Australia. The strategy follows the 2003 passage of a bill that, among other items, recognized the chain of responsibility principle within TSW enforcement. As of 2007, however, not all Australian jurisdictions had adopted the bill's provisions; hence the development of the national strategy. The strategy identifies the following objectives to achieve the national compliance outcome:

  Intelligence-driven enforcement requires information systems that help target enforcement activity and improve detection of violations.
  Consistent, effective, and efficient enforcement practices emphasize co-operation between enforcement agencies and promote a more cohesive relationship between the industry and the regulator.
  Co-operation and trust between industry and the regulator should be fostered to improve compliance.
  Officer training designed to enable confident execution of enforcement tasks.
  Improved communication between enforcement agencies provides an integrated means of recognizing and resolving issues.

- Walker (2010, pp. 17-18) discusses Australia's evolving heavy vehicle regulatory approach, in particular recent implementation of the National Heavy Vehicle Accreditation Scheme (which provides concessions for accredited carriers) and the chain of responsibility principle (which places responsibility for non-compliance on all agents within the logistics supply chain). A series of stakeholder interviews reveals that the accreditation scheme has provided opportunity for better engagement between the regulator and the operators within an innovative and flexible regulatory structure. However, not all operators are interested in participating in such a scheme. Therefore, Walker suggests the need for a two-track regulatory structure, where certain operators demonstrate compliance through the accreditation scheme, while others remain subject to prescriptive regulations and more traditional enforcement. A two-track system has the potential to incentivize compliance and build on innovations already present within the accreditation scheme. However, risks of a two-track system include: unfair competition, complex enforcement, costly implementation, and potential abuse within the self-accreditation program.

- The OECD (2011, pp. 284-288) identifies accreditation as one alternative compliance strategy. Accreditation is a voluntary or mandated arrangement in which an operator certifies compliance with specified regulatory requirements, and the regulator validates compliance through an auditing process. Accreditation schemes have been implemented for the purpose of ensuring compliance with TSW limits, as well as other requirements such as route adherence, cargo handling, and safety. In some schemes, demonstrated compliance within an accreditation scheme enables carriers to operate beyond basic TSW limits. In other words, productivity incentives are used as a means to achieve regulatory compliance for an accredited operator.

Illustrative descriptions of how accreditation schemes have been used within a TSW enforcement program follow:

Australia's National Heavy Vehicle Accreditation Scheme is a voluntary program that allows an accredited carrier to demonstrate compliance (via auditing) and thereby be subject to less frequent on-road enforcement activities. Operators may select to be accredited for maintenance management (which exempts qualified operators from annual inspections), weight management (which allows qualified operators to increase loads), or fatigue management (which provides qualified operators flexibility in hours of service restrictions).

South Africa's Road Transport Management System is a voluntary accreditation scheme designed to improve compliance with weight and safety-related regulations by encouraging industries to take more responsibility for improving on-road safety and limiting infrastructure damage. The scheme is viewed as an instrument which can be used by various agents in the supply chain interested in improving corporate governance.

Another alternative strategy involves the use of the chain of responsibility principle, which is described as follows:

"…all who have control, whether direct or indirect, over a transport operation bear responsibility for conduct which affects compliance and should be made accountable for failure to discharge that responsibility."

This principle can be applied to various aspects of on-road compliance. However, a pertinent example from a TSW perspective is the penalization of a grain handling company which receives grain from overloaded trucks and rewards operators who do so.

Technological adoption and legislative reform are necessary enablers of the chain of responsibility principle. Technologies (e.g., real-time tracking, electronic on-board recording devices) now enable many aspects of a freight transport task to be monitored remotely, thereby placing additional responsibility on the operator for assuring compliance. Legislative reforms that requires all agents within a supply chain to ensure compliance or which reverse the onus of responsibility so that all parties are automatically deemed responsible for non-compliant behavior support the chain of responsibility principle.

- Jones (2012, pp. 8-11) describes aspects of Australia's new enforcement program which includes concepts such as the chain of responsibility and using technology and data to improve enforcement and compliance. To create a culture where TSW laws are nearly self-regulating, Australia is implementing the chain of responsibility concept and trying to achieve voluntary compliance. They are also introducing responsive regulation in legislation that provides regulators with a range of penalties that account for individual company risk and past performance. The lowest penalties require carriers to attend educational sessions which carry no financial impact or issue fines that are a fraction of what would normally be issued. The highest penalties can triple the fine or revoke vehicle or drivers licenses. The chain of responsibility concept has potential to be effective but the author finds that shippers were frustrated with this approach because regulators were unable to provide advice to them about how to manage their obligations when trucks were overloaded. The author concludes that the lack of policy forethought and practical guidance can hinder well-meaning intentions of the industry.

The author also finds the following:

- High-quality and timely data are necessary for regulators to differentiate between low and high risk operators and to provide incentives to compliant operators and target non-compliant operators. However, Australia does not have the system in place to do this at a national level.
- Australia is interested in providing a reward- and incentive-based system for operators to achieve compliance. Some ideas for incentives are to dedicate varying levels of the transportation spending budget to truck-related initiatives based on the level of industry compliance, reduced registration and licensing costs for compliant operators, and reduced insurance premiums.

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Appendix B. Summary of Data Gathered from International Experts on Truck Size and Weight Enforcement

This appendix summarizes data gathered from international experts on truck size and weight enforcement. Data were gathered through telephone/internet calls and via email exchange. Ten experts provided data; these experts included government regulators, researchers, and private consultants from Australia, Canada, France, the Netherlands, New Zealand, South Africa, and the United States.

The following sections provide summary findings organized into the following sections: (1) enforcement needs and approaches, (2) enforcement costs, (3) enforcement benefits, (4) effectiveness of enforcement, (5) application and performance of enforcement technologies, and (6) alternative approaches for achieving compliance.

Enforcement Needs and Approaches

- Increasing allowable truck weight without changing allowable truck and axle configuration should not affect how on-road enforcement is conducted; however, changing the configuration could introduce new costs such as requiring additional enforcement staff training, educating stakeholders about regulatory changes, adjusting regulations, and updating supporting information systems. Increasing the number of axles due to increases in GVW may increase the inspection time for these trucks but likely not significantly more than current inspection times. Further, increasing truck size and weight limits may reduce the number of overweight/oversize permits issued, which has the potential to lower the number of inspections required.
- A shortage of human resources has been identified as a current enforcement issue. This suggests that there may be an opportunity to invest in technologies that can automatically perform enforcement tasks or help enforcement officials more efficiently enforce truck size and weight limits.
- Carriers sometimes express frustration with the varying enforcement practices across jurisdictions, indicating the potential need to pursue harmonization of these practices. Various regulatory and political differences present challenges to achieving this consistency.

Enforcement Costs

- Many jurisdictions struggle with the high and often rising cost of enforcement, particularly those using traditional methods such as roadside inspections. Opportunities to reduce costs include reducing enforcement staff and using technologies such as WIM. Technological implementation has the potential to improve enforcement efficiency and effectiveness despite staff reductions.
- The magnitude of enforcement costs have resulted in a South African benefit-cost analysis to consider the re-allocation of overweight enforcement funding to pavement maintenance.

Enforcement Benefits

- There is insufficient data about enforcement effectiveness and benefits. Anecdotal evidence combined with logical reasoning suggests that increasing enforcement positively correlates with fewer size and weight violations, although experience indicates that this relationship may not be linear.
- There is doubt that a reliable benefit-cost analysis can be achieved particularly due to difficulties in quantifying benefits. Benefits to consider include: (1) fine revenues over time; (2) cost savings in terms of actual enforcement activity; (3) safety benefits (i.e., crashes avoided) by removing overloaded vehicles from the road (not so far possible with available data); and (4) reductions in pavement/bridge damage by removing overloaded vehicles from the road (difficult to do over the lifespan of transport infrastructure with high reliability).

Effectiveness of Enforcement

- Overall, there is uncertainty within the enforcement community about appropriate and feasible enforcement metrics; however, there is general agreement that metrics should be based on compliance rates rather than citation (or violation) rates. Implementing accreditation and auditing programs may be an effective way to measure compliance. Providing incentives (e.g., insurance discounts, increased weight) for accredited carriers can help develop a database that can accurately measure compliance. Measuring the number of inspections and violations is susceptible to providing skewed results since the whole trucking population is not necessarily represented.
- Mobile enforcement seems to be more effective than fixed weigh scales and some jurisdictions have indicated that mobile patrolling of fixed scale by-pass routes can be effective.
- Implementing enforcement and compliance strategies such as the chain of responsibility without providing the resources to prosecute violators does not seem to impact compliance; however, prosecuting even a small sample of violators can create enough deterrence for these programs to be effective.
- Analyzing network-wide WIM data can shed some insight into compliance; however, limited geographic scope and the inability to identify overweight vehicles operating legally with a permit are limitations to this method.
- Recording and collecting data from on-board load cells can provide a metric for compliance, particularly if this technology is adopted by a significant portion of the truck fleet (the adoption of this technology can be stimulated by requiring on-board cells as part of an accreditation program). This technology has been implemented in various jurisdictions including Ontario, where it provides real-time feedback to drivers and indicates whether a vehicle is compliant. An important issue to consider with on-board scales is determining who can install these sensors and who calibrates and maintains them.

Application and Performance of Enforcement Technologies

- There is little evidence or research that quantifies the effectiveness of different enforcement technologies.
- Due to the uncertainty about the effectiveness of different technologies and their ability to perform the multiple duties assigned to an enforcement officer, it is difficult to determine when it is appropriate to implement enforcement technologies. Technologies to assist enforcement personnel in the field (e.g., pre-screening technologies) have demonstrated their usefulness and application. For example, high-speed WIM devices can be used for pre-screening trucks and low-speed WIM devices can be used to inspect potentially overweight trucks identified by the pre-screening WIM device. Some European jurisdictions are moving towards the use of low-speed WIM for issuing citations.
- WIM requires regular calibration, especially low-speed WIM if it is used for issuing citations. Low-speed WIM has been proven to be comparable and in some instances interchangeable with static scales. Further, low-speed WIM can sometimes provide a more accurate weight measurement than static scales since they can minimize the issues associated with springs and shifting weight that can occur when a truck stops (particularly for liquid tankers).

Alternative Approaches for Achieving Compliance

- Anecdotal evidence suggests that the chain of responsibility, accreditation, and the Intelligent Access Program (IAP) in Australia, and virtual weigh scales and targeted enforcement in the U.S., are highly effective. Overall, incentive-based strategies that encourage self-regulation (as opposed to punitive-based strategies imposed by government regulators) appear promising and have already demonstrated perceived success.
- If carriers want the benefits of higher vehicle weights, they should be subjected to higher safety and compliance standards.
- Effective alternative methods for enforcement and achieving compliance include:
    - Chain of responsibility;
    - Accreditation;
    - Intelligent Access Program (IAP) developed in Australia;
    - Virtual weigh scales;
    - Targeted enforcement (i.e., analyzing a network of WIM data to identify roads most susceptible to overweight trucks and deploying mobile units to these areas)
    - Pre-screening using WIM; and
    - On-board scales

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APPENDIX C. COMPLETE PROJECT PLAN

General Approach for this Task

This appendix provides the detailed project plan for USDOT's 2014 *Comprehensive Truck Size and Weight Limits Study* (2014 CTSW Study) *Volume II: Compliance Comparative Analysis*. The document is divided into five main sections:

1. Detailed Project Plan for **Part 1 (Desk Scan)**
2. General Approach for **Part 3 (Estimation of Cost of Enforcement) and Part 4 (Effectiveness of Enforcement)**
3. Detailed Project Plan for **Estimation of Cost of Enforcement**
4. Detailed Project Plan for **Effectiveness of Enforcement**
5. Proposed **Schedule for Completion**

This part of the 2014 CTSW Study will focus on the identification of difference in methods and approaches, effectiveness of methods and approaches and costs associated with inspecting and conducting compliance assessments on trucks operating at or below current Federal truck size and weight limits as compared to conducting the same on trucks operating above those limits. Two steps will be completed under this work: making comparative assessments on the current fleet of trucks operating in the US and making similar comparative assessments on the "alternative configurations" that will be included in this Study.

As part of carrying out the responsibilities of included under this work, it is important to note that success in completing the proposed work hinges on the need to gather the necessary data supporting the technical analysis and assessments to be addressed under this part of the 2014 CTSW Study.

It is envisioned that the following data sources will be used to conduct the required work:

- <u>State Over-size/Over-weight Permitting Data:</u> In consultation with AASHTO's Sub Committee on Highway Transport, State permit data will be accessed and examined in order to identify trucks operating at or below current Federal size and weight limits and trucks that operate above those limits.
- <u>State Enforcement Plans</u>: These plans provide state-specific data concerning resources (e.g., budget, personnel, facilities, equipment) directed at truck size and weight enforcement and information about the environment within which these resources are expended (e.g., extent of network, truck miles traveled).
- <u>Annual Certifications of Truck Size and Weight Enforcement database:</u> This database contains state-specific information on the enforcement of commercial motor vehicle weight (by type of weighing method), violations (by type of violation), load shifting and off-loading requirements, and permit issuance activities.
- <u>Weigh-in-Motion data:</u> WIM data from selected locations (subject to the criteria listed in **Part 4**) will provide a means to assess truck weight compliance by axle group and for the

whole vehicle. The WIM data enable the calculation of the proposed performance measures (see **Part 4**).

- Experiential data and intelligence: The work relies on extensive consultation with industry stakeholders. In particular, State representatives will be asked to provide experiential data to support our analysis. Case studies will be selected to investigate specific issues concerning compliance of alternative vehicle configurations in States where detailed data and/or substantial experience exist.

Part 1: Detailed Project Plan for Desk Scan

Literature Review

A comprehensive search of literature published in the last decade worldwide that will be helpful to this 2014 CTSW Study will be completed with a special focus on compliance and enforcement program costs and the effectiveness of enforcement. The principal objective of the search is to gain a thorough understanding of the current state of research and practice concerning truck weight enforcement and compliance. The literature search will include a variety of information sources: (1) engineering and scientific periodicals and journals; (2) conference proceedings; and (3) readily available government and industry reports. The starting point for this activity will be the final reports from NCHRP 20-07 Tasks 254 and 303. The American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Highway Transport (SCOHT) undertook Task 254 to summarize the activities associated with the international scan in 2006, and completed Task 303 in 2011 principally to respond to Federal truck size and weight study questions.

Beyond these initial resources, the search includes the resources shown below.

Library Catalogues and Conference Proceedings

- Transportation Research International Documentation (TRID)
- American Society for Civil Engineers
- University of Michigan Transportation Research Institute Library
- University of Manitoba Transport Information Group Library
- ScienceDirect
- NRC Research Press
- Transportation Association of Canada

Heavy Vehicle Transport Technology Proceedings Government and Industry Agencies

- Federal Highway Administration (FHWA)
- Federal Motor Carrier Safety Administration (FMCSA)
- The Transportation Research Board (TRB)
- The Transportation Association of Canada
- American Transportation Research Institute
- National Transport Commission (Australia)
- Australian Road Research Board

- Organization for Economic and Community Development (OECD)
- International Transport Forum (ITF)

The search will supplement the following list of key historical material with which we are already familiar:

- *Comprehensive Truck Size and Weight Study* by the U.S. Department of Transportation, 2000 (2000 CTSW Study)
- Relevant special reports by the Transportation Research Board, namely *Special Report 267 Regulation of Weights, Lengths, and Widths of Commercial Motor Vehicles* and *Special Report 225 Truck Weight Limits: Issues and Options*
- Recent truck size and weight reports conducted in Maine, Vermont, Wisconsin, and Minnesota
- *Moving Freight With Better Trucks* by the International Transport Forum
- NCHRP Web Document 13 entitled *Developing Measures of Effectiveness for Truck Weight Enforcement Activities*
- *National Heavy Vehicle Enforcement Strategy Proposal* by the National Transport Commission (Australia)

We envision summarizing the literature according to the following main topics:

- Enforcement needs and approaches (including impacts of changes)
- Enforcement costs
- Enforcement benefits
- Effectiveness of enforcement
- Application and performance of enforcement technologies
- Alternative approaches for achieving compliance

<u>Stakeholder Data Gathering</u>

To supplement the findings of the literature search, we will consult industry stakeholders representing enforcement and permitting programs from selected States, relevant committees within the Commercial Vehicle Safety Alliance (CVSA), AASHTO, and Transportation Research Board (TRB), and international experts from Canada, Europe, and Australia through various data gathering methods. The Appendix contains the areas of interest that we propose to use to guide the data gathering. To comply with the Federal Paperwork Reduction Act we will work through 4 AASHTO regions and through a CVSA Advisory Group of 9 States. Questions and requests for data will be coordinated through these organizations. We propose to include the following agencies (specific individuals are named where possible).

State Officials

Data will be gathered from officials from the following States and their counterparts. These States have been selected because they: (1) are considered to be enforcement programming leaders in the nation; (2) have experience in enforcing vehicles subject to grandfather provisions (e.g., Longer Combination Vehicles-LCV); and/or (3) have recently undertaken research and development projects related to truck size and weight enforcement.

- Colorado (Mark Savage)
- Florida (Keith Westphal)
- Georgia (Gene Davis)
- Idaho
- Indiana (John Hill)
- Maine (Rob Elder)
- Michigan
- Minnesota (Ted Coulianos, Tim Rogotzke, Bill Gardner, or Ward Briggs)
- New Mexico
- New York
- Ohio (Jeff Honefanger)
- Oregon
- Utah
- Vermont
- Washington
- Wisconsin (Peter Lynch or John Corbin)

Representatives from CVSA Committees

Data will be gathered from the following CVSA committee representatives and their State agencies:

- Stephen Keppler, Executive Director
- Size and Weight Committee: Jay Thompson, Chair (Arkansas Highway Police), Tim Levi, Vice Chair (Oklahoma Highway Patrol), and Allen Hook, Secretary (North Carolina State Highway Patrol)
- Driver-Traffic Enforcement Committee: Thomas Fitzgerald, Chair (Massachusetts State Police)
- Information Systems Committee: William Elovirta, Chair (Vermont Department of Motor Vehicles)
- Vehicle Committee: Kerri Wirachowsky, Chair (Ontario Ministry of Transportation)

Representatives from AASHTO's Subcommittee on Highway Transport (SCOHT)

Data will be gathered from the following SCOHT members and their State agencies:

- Mark Gottlieb, Chair (Wisconsin)
- Jeff Honefenger, Vice Chair (Ohio)
- Dan Breeden (Alaska)

- Jay Thompson (Arkansas)
- Alan Frew and Reymundo Rodriguez (Idaho)
- Tommy Thames (Mississippi)
- Jan Skouby (Missouri)
- Gregg Dal Ponte (Oregon)
- Glenn Rowe (Pennsylvania)
- Carol Davis (Texas)
- Anne Ford (Washington)

Representatives from TRB Committees

Data will be gathered from the following TRB committee representatives and their agencies and organizations:

- Truck Size and Weight Committee (AT055), John Woodrooffe, Chair
- Trucking Industry Research Committee (AT060), David Miller, Chair
- Truck and Bus Safety (ANB70), Brenda Lantz, Chair

Representatives from Trucking Industry

Data will be gathered from the following trucking industry representatives and their organizations:

- Trucking associations: American Trucking Associations (Darrin Roth), selected State Motor Truck Associations
- Carriers: Landstar, Wal-Mart Transportation, FedEx Corp, ABF Freight Systems, Con-Way
- Manufacturers: Volvo (Skip Yeakel)

International Experts

Data will be gathered from the following international experts and their organizations:

- Anthony Germanchev, Australian Road Research Board
- Jose Arrendondo, National Transport Commission (Australia)
- Bob Pearson, PTRC (Australia)
- John de Pont, TERNZ Transport Research (New Zealand)
- Hans van Loo, Kalibra (Netherlands)
- Loes Aarts, Ministry of Transport (Netherlands)
- Bernard Jacob, IFSTTAR (France)
- Paul Nordengen, Council for Scientific and Industrial Research (South Africa)
- John Pearson, Council of Deputy Ministers of Transportation and Highway Safety, Ottawa, ON
- David Bradley, Canadian Trucking Alliance
- Rob Tardif, Ontario Ministry of Transportation
- Darren Christle, Manitoba Infrastructure and Transportation, former CVSA President, and current Chair of the Standing Committee of Compliance and Regulatory Affairs of the Canadian Council of Motor Transport Administrators

It is envisioned that a summary of the findings from measurable data gathered from the stakeholders according to the same topics listed above for the literature review will be produced under this part of the 2014 CTSW Study. Findings from the data gathered will be clearly differentiated from literature findings, and will be attributed to the type of stakeholder (e.g., State official, researcher, international expert) generating the findings as possible. The results of the data gathering exercise will be summarized for internal purposes, and may also be reported as part of our deliverables. The information provides a valuable assessment (in addition to the literature) of the current state-of-the-practice.

Part 2: General Approach to Parts 3 (Enforcement Program Costs) and 4 (Effectiveness of Enforcement Programs)

A performance-based approach to estimate the costs of truck size and weight enforcement and analyze enforcement effectiveness will be applied. This approach considers enforcement program performance (or effectiveness) in terms of outputs (which reflect the way resources are used and what they are focused on: i.e., Axle, Tandem Axle, Gross Vehicle Weight and Bridge Formula violations, when conducting enforcement activities) and outcomes (which reflect the degree of success of the enforcement program in achieving compliance), as a function of resource inputs (for example, program costs). The distinction between outputs and outcomes, while subtle, is important because measuring outputs may encourage efforts to increase the quantity of inspections conducted or violations observed and reported, which ideally should decrease in situations where enforcement achieves better compliance. In contrast, outcome-oriented measures may describe the frequency or rate of compliant events (which may suggest successful enforcement) or the severity of over-weight observations (which may suggest a lack of enforcement success). **Table 28** provides example measures within this approach.

Table 28: Example Measures within the Performance-Based Approach

Type of measure	Example measure(s)
Input	• Enforcement program cost • Number of enforcement personnel
Output	• Inspections • Violations • Violation rate as a function of enforcement intensity
Outcome	• Compliant events • Severity of over-weight axles

Application of this approach will provide the supporting framework for a multifaceted analysis designed to reveal insights about the costs and effectiveness of enforcement programs. It is acknowledged that a comprehensive, representative understanding of enforcement costs and effectiveness will be limited by the availability of reliable data. To accommodate these limitations and leverage existing datasets and institutional knowledge, a three-tiered approach will be pursued in completing the analysis for this part of the study as described below:

- *Tier 1*: At the broadest level, relevant performance measures concerning enforcement costs (i.e., inputs) and activities (i.e., outputs) will be gathered at the State level using readily available data sources, supplemented through data gathered from industry stakeholders. The selection of States will be made considering general differences in trucking operations and varying geographic and climatic factors.
- *Tier 2*: The assessment of compliance (i.e., an outcome) will analyze relevant performance measures at specific locations where representative data are available (principally, weigh-in-motion (WIM) data). This assessment enables a more detailed quantitative analysis of certain compliance outcomes (such as the proportion of compliant events or the severity of over-weight observations for specific truck configurations at that location), but constrains the ability to ascertain the effects of enforcement activities on these outcomes. Efforts will be concentrated on examining differences between trucks operating in excess of Federal limits and those operating below Federal limits. This *Tier 2* deserves a little more explanation since it is the most complex. The level of compliance will be used as a way to measure enforcement effectiveness. Compliance will be measured by the degree of extremely over-weight trucks, measuring severity of over-weight axles and axle sets, and the proportion of compliant events, such as compliant axles and axle sets. The severity measure will be calculated as the average weight of all the over-weight observations and then how much this average exceeds the limit. This determination will be based on the configuration of trucks, which has weight implication and the weight limit based on classification. Using FHWA's vehicle classification scheme classes, as defined in the Traffic monitoring Guide, the Class 9 (five-axle tractor-semitrailers) will be used as the foundation truck but will also gather information on other

classes 10-13 (six-axle tractor semitrailers and multiple trailer trucks), which include other configurations being considered for study. This information will be captured for those legally loaded and operating trucks and those extra-legal trucks in order to determine the proportion of compliant trucks within certain classifications at a specific WIM location. The extent to which this is information is aggregated along a corridor/in a region/in a State will be investigated as the study progresses. The determination of a specific enforcement activity related to these over-weight trucks will not be performed but will be useful in making observations toward trucks that are operating in over-weight conditions on these travel-ways. Special focus will be applied to Class 9 trucks and on specific, commonly observed "extra-legal" trucks operating under a "grandfathered provision" (for example, under a State-issued permit or a specific Federal size and weight statutory exemption). For example, Longer Combination Vehicles (LCVs) allowed are allowed to operate, under the ISTEA-Freeze, in certain States at locations where they are known to be operating. Case study data will be examined from certain States where LCVs are allowed to legally operate and will be used to develop the adjustment factor for permits, and to help understand the compliance experience associated with trucks operating under a "grandfathered" right.

- *Tier 3*: The third tier uses case studies to qualitatively investigate enforcement issues concerning alternative truck configurations that are too complex to handle at a larger scale. These case studies will be designed to support the quantitative assessment of compliance conducted in *Tier 2*.

The analysis approach described for **Part 3 (Estimation of Cost of Enforcement)** and **Part 4 (Effectiveness of Enforcement)** will also examine the integration of the alternative truck configuration and scenarios that are being developed for the 2014 CTSW Study as a whole. A more thorough framework for completing this integration will take shape as these scenarios are defined and clarified.

Part 3: Estimation of Cost of Enforcement

Part 3 determines and describes the inputs or resources required to manage and operate a State truck size and weight enforcement program (i.e., a *Tier 1* analysis). Based on the findings from **Part 2**, inspection steps and procedures for the principal truck size and weight enforcement methods used in North America will be summarized, namely: (1) fixed (inspections occurring at static weigh scales, with or without a mainline pre-screening device); (2) roving (mobile officers conducting inspections using portable or semi-portable weighing devices); (3) virtual (inspections occurring using a combination of WIM and video/imaging technologies); and (4) compliance demonstration (where selected carriers are deemed responsible for compliance with all relevant matters, including weight, and are subject to auditing to assure compliance). This work focuses on the enforcement of truck size and weight limits; however, distinguishing enforcement resources directed at truck size and weight from those resources directed at safety or credentials regulations is not always easily performed. We will attempt to distinguish these program areas as far as practicable.

Truck size and weight enforcement program inputs will be gathered from selected State officials conducted as part of work to be addressed as described under **Part 2** and summarized in a tabular format. Program inputs include:

- Annual monetary cost (or budget) of the enforcement program;
- Incremental costs of enforcement, weighings and other actions by configuration type of truck;
- Number of enforcement personnel, the time spent conducting various enforcement activities, and the number of inspections (or weighings) by truck configuration performed by enforcement method;
- Quantity of fixed and mobile enforcement equipment (e.g., scales or patrol cars); and
- Quantity and type of automated enforcement technologies.

The data gathered will reveal information about the relative proportion of available resources directed at specific aspects of the enforcement program. Program aspects to be distinguished include routes and/or networks; industries and/or commodities; truck configurations (specifically those operating within Federal limits and those operating beyond Federal limits); and non-permitted versus permitted trucks. We expect that States may be unable to provide detailed breakdowns concerning some of these aspects; the level of detail available will dictate the specificity of subsequent analyses in **Part 4 (Effectiveness of Enforcement).**

Program cost figures for all States will be calculated from baseline information obtained from the annual certifications provided to FHWA, using staffing figures as a guide to the size of the program and adding the cost information, in proportion to staffing, obtained from selected States. This will help to normalize the data across States. Issues related to accuracy of proportional cost information will be reviewed with CVSA for quality control purposes. Additional normalization of the data will be accomplished through metrics such as highway network distance and truck miles of travel. Program costs will focus on any incremental costs (or cost savings) associated with enforcing regulations governing the alternative truck configurations currently operating in excess of Federal limits in certain States.

Key findings and trends will be summarized and used to assess the enforcement community's ability to sustain viable enforcement programs in the context of potentially expanded use of the alternative truck configurations on specified networks. For example, trends showing budget reductions over time, extra costs and/or time associated with certain methods of enforcement (for certain truck configurations or networks), or investments in new technologies will help assess program viability. This particular component of the analysis will be shaped by further characterization of the scenarios being developed in the other work areas. In order to avoid highlighting States that could be boastful or need high levels of remedial action we plan to work with the States to consolidate findings on a regional basis or along certain corridors of the country.

To support the foregoing analysis, an investigation will be conducted into the costs and performance of existing and near-term enforcement technologies through gathering of experiential data from key technology users and vendors. Special attention will be given to the Smart Roadside Program that both FHWA and FMCSA have been promoting. This program is expected to be a key feature for improving enforcement effectiveness and future productivity. The virtual weigh station (VWS) initiative and wireless roadside inspection (WRI) technologies, two components of Smart Roadside, are already operating in several States across the nation.

Although WRI is focused primarily on safety, any cost implications associated with truck size and weight will be captured in this cost analysis. Findings related to safety will also be considered and integrated into the work being completed in the Highway Safety/Truck Crash Analysis work are of this Project, as applicable.

Part 4: Effectiveness of Enforcement

Work to be completed under **Part 4** will determine and describe the outputs and outcomes of enforcement programs and evaluates effectiveness by developing relationships between resource inputs and program outputs and assessing compliance outcomes. The proposed approach to meet the requirements of this area of the Project involves: (1) compiling and analyzing program outputs at the State level (i.e., a *Tier 1* analysis); (2) assessing compliance outcomes using Weigh-in-Motion (WIM) data collected at representative locations (i.e., a *Tier 2* analysis); and (3) conducting targeted case studies to identify enforcement issues associated with the alternative truck configurations (i.e., a *Tier 3* analysis). In addition, we will identify statutes and regulations pertaining to Federal truck size and weight limits that would be impacted by regulatory changes.

Another important area of investigation included under this Part will be to determine the impact that the introduction of the "alternative configurations" included in this Study will have on the cost of enforcement programs and the impact on resource requirements needed to operate effective truck size and weight enforcement programs. Outputs generated under the Modal Shift work area of this project will be used to define the boundaries for this assessment.

Analysis of Program Outputs

This component analyzes (at a *Tier 1* level) weight enforcement program outputs, including:

- Violations by type (i.e., axle weight, GVW, bridge formula);
- Number of load shifting and offloading vehicles;
- Over-weight permits issued by type (i.e., divisible vs. non-divisible, trip vs. annual); and
- Violation rates, calculated as violations per number of inspections and number of vehicles weighed or by enforcement method.

The output analysis will be conducted on a State-by-State basis using the Annual Certifications of Truck Size and Weight Enforcement Activities dataset. Output measures such as overloads identified and avoided (e.g., through load shifting and/or offloading) are considered direct benefits of an enforcement program. Violations will be interpreted as observed incidents of non-compliance with all applicable size and weight laws and regulations.

An examination into the two relationships to further understand the effectiveness or performance of enforcement using these outputs and the inputs acquired in **Part 3 (Estimation of Cost of Enforcement)**. The relationship between violation rate and *inspection intensity* (i.e., the number of inspections conducted per unit of time devoted to inspections), and between violation rate and *enforcement intensity* (i.e., the number of inspections conducted per unit of truck travel in a geographic region) will be established as part of this work. Previous research conducted in Canada reveals that higher inspection and enforcement intensities (related to traditional on-road activities) lead to lower violation rates, but produce an ever-diminishing return. Essentially, at some point, increases in intensity cause no further decrease in the violation rate. In addition, relevant States will be selected to gain more detailed analysis of these relationships. Specifically, information will be disaggregated by enforcement method (e.g., fixed vs. roving) and vehicle configuration to contribute to a more precise understanding of these relationships. The selection of States will be completed based on data availability (ascertained during the data gathering process) and directed at developing meaningful insights.

<u>Assessment of Compliance Outcomes</u>

Enforcement program effectiveness will also be evaluated based on its ability to meet its main objective: compliance. For this component, compliance is treated as an outcome within the performance-based approach. The compliance assessment occurs in the context of a *Tier 2* analysis, as described earlier. Since directly measuring compliance is difficult, the approach to assessing compliance will be supported by using WIM data to provide an indication of compliance rates and the intensity of over-weight observations (level of over-weight) at selected locations.

The selection of WIM locations to include in the compliance assessment requires consideration of:

- The WIM data requirements of other Reports, such as the pavement and bridge assessments included in the Project, so that quality control and pre-screening efforts can be minimized and standardized;
- The calibration record of WIM equipment;
- The quality and expected accuracy of WIM measurements, which varies by the type of WIM equipment;
- The proximity of a WIM station to a weigh scale;
- The availability of a full year of data to avoid seasonal bias;
- The need to include WIM data representative of various truck operating, geographic, and climatic conditions;
- The need to include WIM data representative of conditions on various highway networks (e.g., Interstate System, national network, etc.);
- The ability to document the enforcement activities undertaken by the State in which the WIM is located (this will be assessed based on findings from **Part 3 (Estimation of Cost of Enforcement**); and
- The ability to identify truck configurations from the WIM database that routinely operate under grandfather provisions, with the aim to isolate these from trucks that may operate under State issued over-size or over-weight permit.

At the selected WIM locations, specific configurations will be identified from the WIM dataset (using standard axle-based classification algorithms) and then analyze the weight data using the following performance measures:

- *Gross vehicle weight compliant, proportion*: the fraction (or percentage) of the total observed truck sample which complies with the legal (static) gross vehicle weight limit.

- *Gross vehicle over-weight, severity*: the extent to which average measured gross vehicle weights for the observed sub-sample of over-weight trucks exceeds the legal (static) gross vehicle weight limit.
- *Steering-axle compliant, proportion*: the fraction (or percentage) of the total observed truck sample for which the steering-axle weight complies with the legal (static) steering-axle weight limit.
- *Steering-axle over-weight, severity*: the extent to which average measured steering-axle weights for the observed sub-sample of trucks with an over-weight steering axle exceeds the legal (static) steering-axle weight limit.
- *Single-axle compliant, proportion*: the fraction (or percentage) of the total observed truck sample for which all single-axle weight observations comply with the legal (static) single-axle weight limit.
- *Single-axle over-weight, severity*: the extent to which average measured single-axle weights for the observed sub-sample of trucks with over-weight single axles exceeds the legal (static) single-axle weight limit.
- *Tandem-axle compliant, proportion*: the fraction (or percentage) of the total observed truck sample for which all tandem-axle weight observations comply with the legal (static) tandem-axle weight limit.
- *Tandem-axle over-weight, severity*: the extent to which average measured tandem-axle weights for the observed sub-sample of trucks with over-weight tandem axles exceeds the legal (static) tandem-axle weight limit.
- *Federal Bridge Formula-B compliant, proportion:* the fraction or percentage of the total observed truck samples determined to comply with the Federal Bridge Formula.
- *Federal Bridge Formula-B violation severity:* the extent to which the average estimated bridge formula violations exceed the calculated value for each observed configuration that would deem it compliant.
- *Tridem-axle compliant, proportion* (if applicable): the fraction (or percentage) of the total observed truck sample for which all tridem-axle weight observations comply with the legal (static) tridem-axle weight limit.
- *Tridem-axle over-weight, severity* (if applicable): the extent to which average measured tridem-axle weights for the observed sub-sample of trucks with over-weight tridem axles exceeds the legal (static) tridem-axle weight limit.

To simplify the analysis, Class 9 trucks (standard five-axle tractor semitrailers) will be used as the base analysis vehicle for all locations. In addition, at certain locations, the truck configurations will be identified from the WIM database that routinely operate under grandfather provisions. Candidate truck configurations will be identified through consultation with State enforcement officials. Scoping the analysis to include only specific vehicle configurations minimizes the potential inclusion of permitted loads, which cannot be identified from the WIM data but which could be measured as over-weight despite being in compliance with permit conditions.

Performance measures listed previously will be used in order to define above as the basis for revealing insights about the compliance experience at the selected WIM locations. These insights will be shaped by knowledge gained about the enforcement practices and intensity in the State where the WIM is located. Specific findings concerning the effects of enforcement on compliance outcomes will be limited by the expected inability to attribute the intensity and type of enforcement activities to the specific WIM location. This issue, in addition to other uncontrolled variables, will also impact the ability to make direct comparisons of the compliance outcomes between WIM locations. Nevertheless, pragmatic insights will be drawn from the compliance assessment, and will select a sufficient number of WIM locations to generate and support these insights, subject to the selection considerations listed above.

When assessing truck weight compliance using WIM data, it is important to note two issues that arise because of the nature of the WIM measurements. First, WIM devices measure axle weights while trucks are in-motion and are therefore subject to the dynamic interactions between the vehicle and the road. As such, an over-weight observation by a WIM may not result in an over-weight observation if the same axle (or truck) is weighed on a static scale. Because of this, our analysis differentiates between an over-weight observation as recorded by a WIM and a violation, which normally arises from a static weighing with reference to a legal (static) load limit.

Second, because most WIM scales are not selective about the trucks they weigh (i.e., it does not target a vehicle for weighing based on the likelihood that it is over-weight), the proportion and severity of over-weight observations is representative of all trucks passing over the scale during the observation period. In contrast, the proportion and severity of over-weight observations at a static weigh scale could reflect targeting of trucks likely to be over-weight. By extension, it is incorrect to assume that the proportion of compliant vehicles observed at a WIM is the same as that observed at a weigh scale.

Case Studies of Alternative Truck Configurations

The case studies (*Tier 3*) investigate and document the enforcement and compliance experience associated with the alternative truck configurations not currently allowed nationwide but which are already in common use (under grandfather provisions or on State roads) in certain States. The investigation supports the quantitative compliance assessment of vehicles operating under grandfather provisions undertaken as part of this work by providing qualitative information obtained through in-depth data gathering. Specifically, we propose to review experiences with the 88,000 lb. five-axle tractor semitrailer (a candidate State for this project is Florida), the 97,000 lb. six-axle tractor semitrailer (this case study may focus on an industry sector, for example hauling of forestry or agricultural products), and LCVs operating in a number of western States or international jurisdictions (for example, States located west of the Mississippi and/or Canadian provinces). Each case study (up to three in total) will attempt to document any specialized or targeted enforcement activities or technologies directed at the alternative vehicle configurations and the results of these efforts within a specific operating context (e.g., in a State as a whole or within a specific industry sector).

Identification of Statutes and Regulations

In this work area, all statutes and regulations pertaining to Federal truck size and weight limits that would be impacted in the event of changes to these limits will be identified. The review will focus on relevant language contained in US Code Title 23: Highways and US Code Title 49: Transportation, as well as the corresponding regulations in the Code of Federal Regulations, Title 23, Part 658 and Code of Federal Regulations, Title 49 that pertain to Federal truck compliance program activities. Consultation with State enforcement personnel responsible for the delivery of truck enforcement program activities will be conducted to ensure the appropriate Federal statutory and regulatory references are identified.

Appendix: Proposed Data Gathering Tools

As discussed in the body of the Project Plan, coordination with the four AASHTO regions (Western Association of State Highway and Transportation Officials [WASHTO], Southern Association of State Highway and Transportation Officials [SASHTO], Mid-American Association State Transportation Officials [MAASTO] and the Northeast Association of State Transportation Officials [NASTO]) and in consultation with CVSA Advisory Group comprised of no more than of nine States related to data gathering. Questions and requests for data will be coordinated through these organizations.

Questions to Guide Data Gathering with State and Industry Stakeholders and Data Experts

Note: Regarding the question on differentiating between at-limit and above-limit States based on gross vehicle weights, a category for States that do not have divisible load permit rights and require trucks to operate at no more than 80,000 pounds will be established with a second category for states that do have grandfathered, divisible load permit rights and allow permitted trucks to operate above 80,000 pounds will also be established. Representative cost information for each of those two categories will be collected from several States. A factor will be developed to be applied to the remaining States. Information developed during the conduct of the desk scan should be helpful in identifying which States have the most reliable and current data available to complete this part of the work.

State Officials

General comment: While conducting the data gathering activities needed to complete this part of the study, States will be identified in which more detailed analysis, especially by vehicle configuration and enforcement methods that are routinely applied, may be most feasible and practical. In addition, this effort will help determine where there are opportunities for relevant vehicle-specific case studies that can be conducted. To identify the States where detailed analysis and case studies may be most appropriate, the following information would be helpful:

- Approaches to and methods employed in truck enforcement program activities –
  - Fixed, stationary scales (weigh-bridges);
  - Mobile enforcement using portable or semi-portable scales;
  - Roadside screening technologies used to identify trucks needing closer compliance checks and measurements.
- Areas of specific enforcement interest –
  - Specific routes and roadway networks;
  - Specific truck configurations or types;
  - Specific commodities being hauled.
- Impacts that a change in truck size and weight limits will have on enforcement program resources, costs and manpower needs.
- Resources that support enforcement programs:
  - Annual budget (i.e., program costs)
  - Number of on-road officers and FTEs (specify if seasonal employment occurs)
  - Number of weighings by fixed and mobile
  - Approximate number of hours conducting inspections (fixed and mobile)
  - Quantity of fixed equipment (i.e., weigh scales)
  - Quantity of mobile equipment (e.g., portable scales, patrol cars)
  - Percentage of resources (in terms of budget, personnel, or FTEs) devoted to safety, weights & dimensions, driver/vehicle credentials.
  - If available, any information on percentage of resources allocated to specific types of truck configurations or highway networks.
- Data used to conduct truck enforcement program activities –
  - WIM for pre-screening mainline truck traffic;
  - Ramp WIM for sorting at weigh station locations;
  - WIM as part of a mainline pre-clearance program;
  - Real-time, roving network connection WIM;
  - Digital photo identification of vehicle;
  - Automatic vehicle identification (AVI);
  - Automated counting at scale;
  - Virtual weigh stations;
  - Wireless roadside inspections technologies;
  - Others

- Scope of enforcement program responsibilities –
  - Number of centerline miles by roadway type and jurisdiction;
  - Number of centerline miles monitored;
  - Truck vehicle miles of travel.
- Benefits, quantified or monetized, identified with truck enforcement program.
- Identification specific enforcement strategies seen to be very effective.
- Alternative compliance techniques being used.
- Methods used to measure enforcement program effectiveness.
- Factors used to evaluate program effectiveness and monitor program performance
- Long term trends in resources availability and program performance.
- Recent studies or reports completed on truck enforcement program performance or program effectiveness.
- Truck size and weight enforcement cost analysis information or data.

Representatives from CVSA Committees

Several of the previously identified data elements are relevant for data collection from State enforcement program personnel. A number of additional data elements are also needed:

- Program cost information associated with State enforcement agencies in conducting truck enforcement program activities.
- Over-size and over-weight (os/ow) permit data and information.
- Oversight responsibilities for permit compliance and enforcement.

Representatives from AASHTO SCOHT (State Regulatory Personnel)

Note: These are primarily the motor carrier safety program and regulatory personnel within State Departments of Transportation but, in some States, are assigned to Public Safety Agencies, Departments of Motor Vehicles and Department of Revenue agencies across the country. They generally differ from State law enforcement people.

- Availability of os/ow permit data.
- Locations and regions or sub-regions of the State where permits are most frequently used.
- Breakdown of permits by type (radial, annual, single trip, etc.).
- Vehicle weights that are most frequently issued permits.
- Enforcement personnel's access to permit information.
- Divisible load permits associated with vehicle weight (number of permits and weight that can be permitted).
- Availability to permitting program requirements and allowances.
- Intensity of permit usage by type of commodity.
- Permit compliance monitoring and enforcement activities.

Representatives from TRB Committees

Representatives of the various TRB Committees referenced previously are seen as sources of more specific information on truck enforcement practices and research and in providing insights into enforcement program activities internationally. Consultation with Committee members will be conducted as needed.

Representatives from the Trucking Industry

Consultation with trucking industry representatives will be completed to ascertain enforcement program and technique effectiveness from their perspective. It is not envisioned that specific data elements will be pursued from these stakeholders.

International Experts

Practices and techniques in truck size and weight enforcement have the potential of contributing to understanding the additional cost to enforcement in resources and manpower for overseeing the operation of the alternative configurations included in the 2014 CTSW Study. The following data elements were felt to be beneficial if attained from truck size and weight personnel from other countries –

1. Size and weight (dimension and mass) limits for commercial motor vehicles.
2. Impacts that changes in truck size and weight regulations have had on enforcement program effectiveness.
3. Benefits, quantified or monetized, of truck weight enforcement.
4. Technologies used for truck weight enforcement.
5. Enforcement strategies effectiveness.
6. Alternative compliance techniques and their effectiveness.
7. Measures used for enforcement effectiveness.
8. Methods used to monitor or evaluate enforcement program activities.
9. Recent studies or reports completed in the area of truck size and weight enforcement.

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APPENDIX D. IDENTIFICATION OF AFFECTED STATUTES AND REGULATIONS

This appendix identifies statutes and regulations that would be impacted by the widespread operation of alternative truck configurations on all roads and highways on which Surface Transportation Assistance Act (STAA) vehicles can now operate. The review focuses on relevant language contained in:

- US Code Title 23: Highways
- US Code Title 49: Transportation
- Code of Federal Regulations, Title 23, Part 658 and Title 49 Parts 390-399

U.S. Code Title 23, Section 127 on Vehicle Weight Limitations on the Interstate System and its corresponding regulations contained in the Code of Federal Regulations Title 23, Part 658, are primarily administered by Federal Highway Administration. U.S. Code Title 49, Chapter 311 on Commercial Motor Vehicle Safety, Sections 31111–31115 on length and width limitations are administered by FHWA, but enforced, as safety requirements, through Federal Motor Carrier Safety Administration (FMCSA) regulations. The length and width limitations from Title 49 are contained in the same regulations administered by FHWA. These are in the Code of Federal Regulations Title 23, Part 658.

U.S. Code Title 23, Section 127 – Vehicles Weight Limitations—Interstate System

The United States statutes (U.S. Code) covering vehicle weight limitations on the Interstate System for commercial vehicles are included in Title 23 of the U.S. Code, Section 127. Current statutory language from the relevant passages of this section are included in their entirety in the chart that follows along with the comments associated with sections impacted by a change in Federal truck size and weight limits. Additionally, to aid in the referencing of sections that would be impacted by a change in current Federal truck size and weight limits, the specific language impacted is underlined in the current statutory language.

Current Statutory Language	Impacts
(a) In General.— (1) The Secretary shall withhold 50 percent of the apportionment of a State under section 104 (b)(1) in any fiscal year in which the State does not permit the use of The Dwight D. Eisenhower System of Interstate and Defense Highways within its boundaries by vehicles with a weight of <u>twenty thousand pounds</u> carried on any one axle, including enforcement tolerances, or with a tandem axle weight of <u>thirty-four thousand pounds</u>, including enforcement tolerances, or a gross weight of at least <u>eighty thousand pounds</u> for vehicle combinations of five axles or more.	The reference to gross vehicle weight would be impacted if certain configurations included in the study were adopted.

Current Statutory Language	Impacts
(2) However, the maximum gross weight to be allowed by any State for vehicles using The Dwight D. Eisenhower System of Interstate and Defense Highways shall be twenty thousand pounds carried on one axle, including enforcement tolerances, and a tandem axle weight of thirty-four thousand pounds, including enforcement tolerances and with an overall maximum gross weight, including enforcement tolerances, on a group of two or more consecutive axles produced by application of the following formula: $W = 500\left(\frac{LN}{N-1} + 12N + 36\right)$ where W equals overall gross weight on any group of two or more consecutive axles to the nearest five hundred pounds, L equals distance in feet between the extreme of any group of two or more consecutive axles, and N equals number of axles in group under consideration, except that two consecutive sets of tandem axles may carry a gross load of thirty-four thousand pounds each providing the overall distance between the first and last axles of such consecutive sets of tandem axles (1) is thirty-six feet or more, or (2) in the case of a motor vehicle hauling any tank trailer, dump trailer, or ocean transport container before September 1, 1989, is 30 feet or more: Provided, That such overall gross weight may not exceed eighty thousand pounds, including all enforcement tolerances, except for vehicles using Interstate Route 29 between Sioux City, Iowa, and the border between Iowa and South Dakota or vehicles using Interstate Route 129 between Sioux City, Iowa, and the border between Iowa and Nebraska, and except for those vehicles and loads which cannot be easily dismantled or divided and which have been issued special permits in accordance with applicable State laws, or the corresponding maximum weights permitted for vehicles using the public highways of such State under laws or regulations established by appropriate State authority in effect on July 1, 1956, except in the case of the overall gross weight of any group of two or more consecutive axles on any vehicle (other than a vehicle comprised of a motor vehicle hauling any tank trailer, dump trailer, or ocean transport container on or after September 1, 1989), on the date of enactment of the Federal-Aid Highway Amendments of 1974, whichever is the greater.	Paragraph (2) refers to the Bridge Formula B (BFB), which governs weights on the Interstate System. It would be potentially impacted if the six-axle, 97,000-pound truck or five-axle, 88,000=pound truck are adopted; neither comply with the Federal bridge formula as written in this section. The truck configurations shown in **Table 2** that would not comply with bridge formula calculated limits are the 88,000-pound five-axle, the 97,000-pound six-axle, and the 129,000-pound nin-axle configurations. For those configurations to comply with the bridge formula, allowances for non-compliance with the formula or modifications to the formula would be needed. Also, paragraph (2) would be impacted by any new axle or gross vehicle weights limits enacted.
(d) Longer Combination Vehicles.— (1) Prohibition.— (A) General continuation rule.— A longer combination vehicle may continue to operate only if the longer combination vehicle	If triple trailer combinations are allowed for use on Interstate System and the National Highway System and

Current Statutory Language	Impacts
configuration type was authorized by State officials pursuant to State statute or regulation conforming to this section and in actual lawful operation on a regular or periodic basis (including seasonal operations) on or before June 1, 1991, or pursuant to section 335 of the Department of Transportation and Related Agencies Appropriations Act, 1991 (104 Stat. 2186).	the National Network there would need to be an amendment to this section reflecting the new date of enactment of the allowance referenced.
(B) Applicability of State laws and regulations.— All such operations shall continue to be subject to, at the minimum, all State statutes, regulations, limitations and conditions, including, but not limited to, routing-specific and configuration-specific designations and all other restrictions, in force on June 1, 1991; except that subject to such regulations as may be issued by the Secretary pursuant to paragraph (5) of this subsection, the State may make minor adjustments of a temporary and emergency nature to route designations and vehicle operating restrictions in effect on June 1, 1991, for specific safety purposes and road construction.	This section would be impacted through adoption of the triple trailer combinations for broader mobility privileges.
(C) Wyoming.— In addition to those vehicles allowed under subparagraph (A), the State of Wyoming may allow the operation of additional vehicle configurations not in actual operation on June 1, 1991, but authorized by State law not later than November 3, 1992, if such vehicle configurations comply with the single axle, tandem axle, and bridge formula limits set forth in subsection (a) and do not exceed 117,000 pounds gross vehicle weight.	This paragraph for Wyoming would be impacted and need to be amended if triple trailer combinations with 28 or 28.5-foot trailers and 9 or 10 axles weighing 129,000 pounds are allowed.
(D) Ohio.— In addition to vehicles which the State of Ohio may continue to allow to be operated under subparagraph (A), such State may allow longer combination vehicles with 3 cargo carrying units of 281/2 feet each (not including the truck tractor) not in actual operation on June 1, 1991, to be operated within its boundaries on the 1-mile segment of State of Ohio Route 7 which begins at and is south of exit 16 of the Ohio Turnpike.	This paragraph would be impacted and may need to be changed since Ohio is now allowed 115,000 pounds on triple trailer combinations and could need to allow 129,000 pounds to accommodate scenario vehicles.
(E) Alaska.— In addition to vehicles which the State of Alaska may continue to allow to be operated under subparagraph (A), such State may allow the operation of longer combination vehicles which were not in actual operation on June 1, 1991, but which were in actual operation prior to July 5, 1991.	This section would be impacted in light of the July 5th date, if the triple trailer combination is adopted. Alaska is exempt from Interstate System weight laws.
(F) Iowa — In addition to vehicles that the State of Iowa may continue to allow to be operated under subparagraph (A), the State may allow longer combination vehicles that were not in actual operation on June 1, 1991, to be operated on Interstate	This section would be impacted. There would not need to be any adjustment to this statutory language, but

Current Statutory Language	Impacts
Route 29 between Sioux City, Iowa, and the border between Iowa and South Dakota or Interstate Route 129 between Sioux City, Iowa, and the border between Iowa and Nebraska.	there would need to be adjustments if triple trailer combinations are adopted by Congress, since lengths and widths are restricted below those configurations.
(2) Additional State restrictions.— (A) In general. — Nothing in this subsection shall prevent any State from further restricting in any manner or prohibiting the operation of longer combination vehicles otherwise authorized under this subsection; except that such restrictions or prohibitions shall be consistent with the requirements of sections 31111–31114 of title 49.	If the restriction is lifted for triple trailer combinations then this paragraph would be impacted and need to be modified.
(B) Minor adjustments. — Any State further restricting or prohibiting the operations of longer combination vehicles or making minor adjustments of a temporary and emergency nature as may be allowed pursuant to regulations issued by the Secretary pursuant to paragraph (5) of this subsection, shall, within 30 days, advise the Secretary of such action, and the Secretary shall publish a notice of such action in the Federal Register.	This paragraph may not need to be modified. It appears to fit within the context of lifting some LCV restrictions but not lifting others.
(3) Publication of list.— (A) Submission to secretary.— Within 60 days of the date of the enactment of this subsection, each State (i) shall submit to the Secretary for publication in the Federal Register a complete list of (I) all operations of longer combination vehicles being conducted as of June 1, 1991, pursuant to State statutes and regulations; (II) all limitations and conditions, including, but not limited to, routing-specific and configuration-specific designations and all other restrictions, governing the operation of longer combination vehicles otherwise prohibited under this subsection; and (III) such statutes, regulations, limitations, and conditions; and (ii) shall submit to the Secretary copies of such statutes, regulations, limitations, and conditions.	This paragraph may be impacted if triple trailer combinations are adopted. Relevant modifications would be needed for any modifications made to LCV allowances and would need to reflect the new grandfather date. Also, it may need to separate the LCVs reviewed and analyzed in this Study versus those LCVs that were not studied and will continue to operate under the June 1, 1991 restriction.
(B) Interim list. — Not later than 90 days after the date of the enactment of this subsection, the Secretary shall publish an interim list in the Federal Register, consisting of all information submitted pursuant to subparagraph (A). The Secretary shall review for accuracy all information submitted by the States pursuant to subparagraph (A) and shall solicit and consider public comment on the accuracy of all such	No impact is specifically noted; the utility of this section is questionable if modifications to LCV freeze provisions are adopted.

Current Statutory Language	Impacts
information.	
(C) Limitation.— No statute or regulation shall be included on the list submitted by a State or published by the Secretary merely on the grounds that it authorized, or could have authorized, by permit or otherwise, the operation of longer combination vehicles, not in actual operation on a regular or periodic basis on or before June 1, 1991.	This paragraph would be impacted. It is relevant for any modification of LCV allowances and would need to reference the enactment as separate from the 1991 enactment.
(D) Final list.— Except as modified pursuant to paragraph (1)(C) of this subsection, the list shall be published as final in the Federal Register not later than 180 days after the date of the enactment of this subsection. In publishing the final list, the Secretary shall make any revisions necessary to correct inaccuracies identified under subparagraph (B). After publication of the final list, longer combination vehicles may not operate on the Interstate System except as provided in the list.	This paragraph would be relevant for any modification of LCV allowances.
(E) Review and correction procedure. — The Secretary, on his or her own motion or upon a request by any person (including a State), shall review the list issued by the Secretary pursuant to subparagraph (D). If the Secretary determines there is cause to believe that a mistake was made in the accuracy of the final list, the Secretary shall commence a proceeding to determine whether the list published pursuant to subparagraph (D) should be corrected. If the Secretary determines that there is a mistake in the accuracy of the list the Secretary shall correct the publication under subparagraph (D) to reflect the determination of the Secretary.	This paragraph may be relevant for any modification of LCV allowances. The new enactment date would also be referenced.

U.S. Code Title 49, Chapter 311 – Commercial Motor Vehicle Safety, Subchapter II – Length and Width Limitations

The United States statutes (U.S. Code) covering length and width limitations for commercial vehicles are included in Title 49 of the U.S. Code, Chapter 311. More specifically, the length and width limitations are included in Subchapter II of Chapter 311. Specific sections of relevance are Sections 31111, 31112, and 31114. Current statutory language from the relevant passages of these sections are included in their entirety in the chart that follows, along with the comments associated with sections impacted by a change in Federal truck size and weight limits. Additionally, to aid in referencing sections that would be impacted by a change in current Federal truck size and weight limits, the specific language impacted is underlined in the current statutory language.

Current Statutory Language	Impacts
§ 31111 - Length Limitations (b) General Limitations.— (1) Except as provided in this section, a State may not prescribe or enforce a regulation of commerce that— (A) imposes a vehicle length limitation of less than 45 feet on a bus, of less than 48 feet on a semitrailer operating in a truck tractor-semitrailer combination, or of less than 28 feet on a semitrailer or trailer operating in a truck tractor-semitrailer-trailer combination, on any segment of the Dwight D. Eisenhower System of Interstate and Defense Highways (except a segment exempted under subsection (f) of this section) and those classes of qualifying Federal-aid Primary System highways designated by the Secretary of Transportation under subsection (e) of this section; (B) imposes an overall length limitation on a commercial motor vehicle operating in a truck tractor-semitrailer or truck tractor-semitrailer-trailer combination; (C) has the effect of prohibiting the use of a semitrailer or trailer of the same dimensions as those that were in actual and lawful use in that State on December 1, 1982; (D) imposes a vehicle length limitation of not less than or more than 97 feet on all driveaway saddlemount vehicle transporter combinations; (E) has the effect of prohibiting the use of an existing semitrailer or trailer, of not more than 28.5 feet in length, in a truck tractor-semitrailer-trailer combination if the semitrailer or trailer was operating lawfully on December 1, 1982, within a 65-foot overall length limit in any State; or (F) imposes a limitation of less than 46 feet on the distance from the kingpin to the center of the rear axle on trailers used exclusively or primarily in connection with motorsports competition events. (2) A length limitation prescribed or enforced by a State under paragraph (1)(A) of this subsection applies only to a semitrailer or trailer and not to a truck tractor.	If twin 33-foot double- and triple-trailer combinations are adopted for use on the Interstate System, the dates referenced in the existing statutes would need to reflect any changes in relevant dates associated with those specific configurations considered to be allowed. In addition, the overall length limit for twin 33-foot doubles will exceed 65 feet, and therefore accommodation will need to be made for that. Additionally, (b)(1)(A) would need to be modified with 33 feet replacing 28 feet, (b)(1)(C) would need to be removed, and (b)(1)(E) would need to be removed.
(e) Qualifying Highways. — The Secretary by regulation shall designate as qualifying Federal-aid Primary System highways those highways of the Federal-aid Primary System in existence on June 1, 1991, that can accommodate safely the applicable vehicle lengths provided in this section.	
§ 31112 - Property-carrying Unit Limitation (a) Definitions.— In this section—	If the twin 33-foot double- and triple-trailer combinations are permitted to operate around the

Current Statutory Language	Impacts
(1) "property-carrying unit" means any part of a commercial motor vehicle combination (except the truck tractor) used to carry property, including a trailer, a semitrailer, or the property-carrying section of a single unit truck. (2) the length of the property-carrying units of a commercial motor vehicle combination is the length measured from the front of the first property-carrying unit to the rear of the last property-carrying unit. (b) General Limitations.— A State may not allow by any means the operation, on any segment of the Dwight D. Eisenhower System of Interstate and Defense Highways and those classes of qualifying Federal-aid Primary System highways designated by the Secretary of Transportation under section 31111 (e) of this title, of any commercial motor vehicle combination (except a vehicle or load that cannot be dismantled easily or divided easily and that has been issued a special permit under applicable State law) with more than one property-carrying unit (not including the truck tractor) whose property-carrying units are more than— (1) the maximum combination trailer, semitrailer, or other type of length limitation allowed by law or regulation of that State before June 2, 1991; or (2) the length of the property-carrying units of those commercial motor vehicle combinations, by specific configuration, in actual, lawful operation on a regular or periodic basis (including continuing seasonal operation) in that State before June 2, 1991.	country, and the States would be allowed to permit their operation, this section would not need to be changed. If Federal law stated that permits would not be needed for these types of combinations, then allowance would need to be made in this section for these configurations.
(c) Special Rules for Wyoming, Ohio, Alaska, Iowa, and Nebraska.— In addition to the vehicles allowed under subsection (b) of this section— (1) Wyoming may allow the operation of additional vehicle configurations not in actual operation on June 1, 1991, but authorized by State law not later than November 3, 1992, if the vehicle configurations comply with the single axle, tandem axle, and bridge formula limits in section 127 (a) of title 23 and are not more than 117,000 pounds gross vehicle weight;	This paragraph would need to be modified to reflect a new enactment date for any alternative configuration provided greater mobility privileges. A modification to the gross weight limit noted would need to be applied if triple-trailer combinations of 129,000 pounds gross vehicle weight are allowed.
(d) Additional Limitations.— (1) A commercial motor vehicle combination whose operation in a State is not prohibited under subsections (b) and (c) of this section may continue to operate in the State on highways described in subsection (b) only if at least in compliance with all State laws, regulations, limitations, and conditions, including routing-specific and configuration-specific	This section would need to be amended to reflect the date of enactment for any configuration considered in this study to be allowed greater mobility privileges.

Current Statutory Language	Impacts
designations and all other restrictions in force in the State on June 1, 1991. However, subject to regulations prescribed by the Secretary under subsection (g)(2) of this section, the State may make minor adjustments of a temporary and emergency nature to route designations and vehicle operating restrictions in effect on June 1, 1991, for specific safety purposes and road construction. (2) This section does not prevent a State from further restricting in any way or prohibiting the operation of any commercial motor vehicle combination subject to this section, except that a restriction or prohibition shall be consistent with this section and sections 31113 (a) and (b) and 31114 of this title. (3) A State making a minor adjustment of a temporary and emergency nature as authorized by paragraph (1) of this subsection or further restricting or prohibiting the operation of a commercial motor vehicle combination as authorized by paragraph (2) of this subsection shall advise the Secretary not later than 30 days after the action. The Secretary shall publish a notice of the action in the Federal Register. (4) [1] Nebraska may continue to allow to be operated under paragraphs (b)(1) and (b)(2) of this section, [2] the State of Nebraska may allow longer combination vehicles that were not in actual operation on June 1, 1991 to be operated within its boundaries to transport sugar beets from the field where such sugar beets are harvested to storage, market, factory or stockpile or from stockpile to storage, market or factory. This provision shall expire on February 28, 1998.	
(e) List of State Length Limitations.— (1) Not later than February 16, 1992, each State shall submit to the Secretary for publication a complete list of State length limitations applicable to commercial motor vehicle combinations operating in the State on the highways described in subsection (b) of this section. The list shall indicate the applicable State laws and regulations associated with the length limitations. If a State does not submit the information as required, the Secretary shall complete and file the information for the State. (2) Not later than March 17, 1992, the Secretary shall publish an interim list in the Federal Register consisting of all information submitted under paragraph (1) of this subsection. The Secretary shall review for accuracy all information submitted by a State under paragraph (1) and shall solicit and consider public comment on the accuracy of the information. (3) A law or regulation may not be included on the list	(e) May be removed or modified at the discretion of Congress. In either case, it will be impacted by any change in truck size and weight limits being assessed in the 2014 CTSW Study.

Current Statutory Language	**Impacts**
submitted by a State or published by the Secretary merely because it authorized, or could have authorized, by permit or otherwise, the operation of commercial motor vehicle combinations not in actual operation on a regular or periodic basis before June 2, 1991. (4) Except as revised under this paragraph or paragraph (5) of this subsection, the list shall be published as final in the Federal Register not later than June 15, 1992. In publishing the final list, the Secretary shall make any revisions necessary to correct inaccuracies identified under paragraph (2) of this subsection. After publication of the final list, commercial motor vehicle combinations prohibited under subsection (b) of this section may not operate on the Dwight D. Eisenhower System of Interstate and Defense Highways and other Federal-aid Primary System highways designated by the Secretary except as published on the list. The list may be combined by the Secretary with the list required under section 127 (d) of title 23. (5) On the Secretary's own motion or on request by any person (including a State), the Secretary shall review the list published under paragraph (4) of this subsection. If the Secretary decides there is reason to believe a mistake was made in the accuracy of the list, the Secretary shall begin a proceeding to decide whether a mistake was made. If the Secretary decides there was a mistake, the Secretary shall publish the correction.	
§ 31114 - Access to the Interstate System (a) Prohibition on Denying Access.— A State may not enact or enforce a law denying to a commercial motor vehicle subject to this subchapter or subchapter I of this chapter reasonable access between— (1) the Dwight D. Eisenhower System of Interstate and Defense Highways (except a segment exempted under section 31111 (f) or 31113 (e) of this title) and other qualifying Federal-aid Primary System highways designated by the Secretary of Transportation; and (2) terminals, facilities for food, fuel, repairs, and rest, and points of loading and unloading for household goods carriers, motor carriers of passengers, or any truck tractor-semitrailer combination in which the semitrailer has a length of not more than 28.5 feet and that generally operates as part of a vehicle combination described in section 31111 (c) of this title. (b) Exception.— This section does not prevent a State or local government from imposing reasonable restrictions, based on safety considerations, on a truck tractor-semitrailer	Under paragraph (2) in this section, reference is made to section 31111[c] as it relates to vehicle combinations having access to certain facilities. That section would still remain as the referenced source if it is changed to enable the legal use of the alternative configurations. If the twin 33-foot doubles are allowed STAA mobility privileges, the reference to the 28.5-foot length would be replaced with 33 feet.

Current Statutory Language	Impacts
combination in which the semitrailer has a length of not more than 28.5 feet and that generally operates as part of a vehicle combination described in section 31111 (c) of this title.	

Code of Federal Regulations Title 23 Part 658 – Truck Size and Weight, Route Designations – Length, Width and Weight Limitations

The purpose of Part 658 of the Code of Federal Regulations Title 23 is to identify a National Network (NN) of highways available to vehicles authorized by provisions of the Surface Transportation Assistance Act of 1982 (STAA) as amended, and to prescribe national policies that govern truck and over-the-road bus size and weight. The NN includes the Interstate System plus other qualifying Federal-aid Primary System Highways.

Current statutory language from the relevant passages of this part is included in its entirety in the chart that follows, along with the comments associated with sections impacted by a change in Federal truck size and weight limits. Additionally, to aid in the referencing of sections that would be impacted by a change in current Federal truck size and weight limits, the specific language impacted is underlined in the current statutory language.

Current Statutory Language	Impacts
§ 658.5 Definitions. *Single axle weight.* The total weight transmitted to the road by all wheels whose centers may be included between two parallel transverse vertical planes 40 inches apart, extending across the full width of the vehicle. The Federal single axle weight limit on the Interstate System is 20,000 pounds. *Tandem axle weight.* The total weight transmitted to the road by two or more consecutive axles whose centers may be included between parallel transverse vertical planes spaced more than 40 inches and not more than 96 inches apart, extending across the full width of the vehicle. The Federal tandem axle weight limit on the Interstate System is 34,000 pounds. Tractor or Truck tractor. The noncargo carrying power unit that operates in combination with a semitrailer or trailer, except that a truck tractor and semitrailer engaged in the transportation of automobiles may transport motor vehicles on part of the power unit, and a truck tractor equipped with a dromedary unit operating in combination with a semitrailer transporting Class 1 explosives and/or any munitions related security material as specified by the U.S. Department of Defense in compliance with 49 CFR 177.835 may use the	There may need to be a definition for a tridem axle weight if the 97,000-pound, six-axle truck is considered for legal adoption.

Current Statutory Language	Impacts
dromedary unit to carry a portion of the cargo. Truck-tractor semitrailer-semitrailer. In a truck-tractor semitrailer-semitrailer combination vehicle, the two trailing units are connected with a “B-train” assembly. The B-train assembly is a rigid frame extension attached to the rear frame of a first semitrailer which allows for a fifth wheel connection point for the second semitrailer. This combination has one less articulation point than the conventional “A dolly” connected truck-tractor semitrailer-trailer combination.	
§ 658.13 Length. (a) The length provisions of the STAA apply only to the following types of vehicle combinations: (1) Truck tractor-semitrailer (2) Truck tractor-semitrailer-trailer. The length provisions apply only when these combinations are in use on the National Network or in transit between these highways and terminals or service locations pursuant to § 658.19. (b) The length provisions referred to in paragraph (a) of this section include the following: (1) No State shall impose a length limitation of less than 48 feet on a semitrailer operating in a truck tractor-semitrailer combination. (2) No State shall impose a length limitation of less than 28 feet on any semitrailer or trailer operating in a truck tractor-semitrailer-trailer combination. (3) No State shall impose an overall length limitation on commercial vehicles operating in truck tractor-semitrailer or truck tractor-semitrailer-trailer combinations. (4) No State shall prohibit commercial motor vehicles operating in truck tractor-semitrailer-trailer combinations. (5) No State shall prohibit the operation of semitrailers or trailers which are 281/2 feet long when operating in a truck tractor-semitrailer-trailer combination if such a trailer or semitrailer was in actual and lawful operation on December 1, 1982, and such combination had an overall length not exceeding 65 feet. (c) State maximum length limits for semitrailers operating in a truck tractor-semitrailer combination and semitrailers and trailers operating in a truck tractor-semitrailer-trailer combination are subject to the following: (1) No State shall prohibit the use of trailers or semitrailers of	The length provisions may need to be modified to also apply to any configurations adopted from the 2014 CTSW Study. Section (2)(b)(2) would be impacted if twin 33-foot doubles are adopted. Section (b)(5) would be impacted if twin 33-foot doubles and triple trailer combinations are adopted. In (3)(i), a modification would be required to the phrase, “if grandfathered” should Congress adopt triple-trailer combinations for operation across the Nation. Also Section (3)(h) would be impacted; there would be a need to revise the length limitation based upon the overall length of twin 33-foot doubles.

Current Statutory Language	Impacts
such dimensions as those that were in actual and lawful use in such State on December 1, 1982, as set out in appendix B of this part. (2) If on December 1, 1982, State length limitations on a semitrailer were described in terms of the distance from the kingpin to rearmost axle, or end of semitrailer, the operation of any semitrailer that complies with that limitation must be allowed. (3) Truck-tractor semitrailer-semitrailer. (i) Truck-tractor semitrailer-semitrailer combination vehicles are considered to be specialized equipment. No State shall impose a length limitation of less than 28 feet on any semitrailer or 281/2 feet if the semitrailer was in legal operation on December 1, 1982, operating in a truck-tractor semitrailer-semitrailer combination. No State shall impose an overall length limitation on a truck-tractor semitrailer-semitrailer combination when each semitrailer length is 28 feet, or 281/2 feet if grandfathered. (ii) The B-train assembly is excluded from the measurement of trailer length when used between the first and second trailer of a truck-tractor semitrailer-semitrailer combination vehicle. However, when there is no semitrailer mounted to the B-train assembly, it will be included in the length measurement of the semitrailer, the length limitation in this case being 48 feet, or longer if grandfathered. (h) Truck-tractors, pulling 2 trailers or semitrailers, used to transport custom harvester equipment during harvest months within the State of Nebraska may not exceed 81 feet 6 inches.	
§ 658.17 Weight. (a) The provisions of the section are applicable to the National System of Interstate and Defense Highways and reasonable access thereto. (b) The maximum gross vehicle weight shall be 80,000 pounds except where lower gross vehicle weight is dictated by the bridge formula. (c) The maximum gross weight upon any one axle, including any one axle of a group of axles, or a vehicle is 20,000 pounds. (d) The maximum gross weight on tandem axles is 34,000 pounds. (e) No vehicle or combination of vehicles shall be moved or operated on any Interstate highway when the gross weight on	The weight references in this section would be impacted in accordance with new weight allowances if they are adopted. Paragraph (e) would be impacted if the 97,000-pound, six-axle truck or 88,000-pound, five-axle truck are adopted; they would not comply with Federal Bridge Formula. Paragraph (f) would be impacted and would need to be adjusted to reflect higher weights if adopted. The grandfathered dates for weight

Current Statutory Language	Impacts
two or more consecutive axles exceeds the limitations prescribed by the following formula, referred to as the Bridge Gross Weight Formula: $W = 500\left(\frac{LN}{N-1} + 12N + 36\right)$ Except that two consecutive sets of tandem axles may carry a gross load of 34,000 pounds each if the overall distance between the first and last axle is 36 feet or more. In no case shall the total gross weight of a vehicle exceed 80,000 pounds. (f) Except as provided herein, States may not enforce on the Interstate System vehicle weight limits of less than 20,000 pounds on a single axle, 34,000 pounds on a tandem axle, or the weights derived from the Bridge Formula, up to a maximum of 80,000 pounds, including all enforcement tolerances. States may not limit tire loads to less than 500 pounds per inch of tire or tread width, except that such limits may not be applied to tires on the steering axle. States may not limit steering axle weights to less than 20,000 pounds or the axle rating established by the manufacturer, whichever is lower. (g) The weights in paragraphs (b), (c), (d), and (e) of this section shall be inclusive of all tolerances, enforcement or otherwise, with the exception of a scale allowance factor when using portable scales (wheel-load weighers). The current accuracy of such scales is generally within 2 or 3 percent of actual weight, but in no case shall an allowance in excess of 5 percent be applied. Penalty or fine schedules which impose no fine up to a specified threshold, i.e., 1,000 pounds, will be considered as tolerance provisions not authorized by 23 U.S.C. 127. (h) States may issue special permits without regard to the axle, gross, or Federal Bridge Formula requirements for nondivisible vehicles or loads. (i) The provisions of paragraphs (b), (c), and (d) of this section shall not apply to single-, or tandem-axle weights, or gross weights legally authorized under State law on July 1, 1956. The group of axles requirement established in this section shall not apply to vehicles legally grandfathered under State groups of axles tables or formulas on January 4, 1975. Grandfathered weight limits are vested on the date specified by Congress and remain available to a State even if it chooses to adopt a lower weight limit for a time. (j) The provisions of paragraphs (c) through (e) of this section shall not apply to the operation on Interstate Route 68 in Allegany and Garrett Counties, Maryland, of any	limits provisions in paragraph (i) will need to be changed for any configuration adopted that may be above the STAA five-axle, 80,000-pound combination and the twin 28-foot or 28.5-foot 80,000-pound doubles. In Paragraph (m), the legally allowed vehicles were primarily dump trucks.

Current Statutory Language	Impacts
specialized vehicle equipped with a steering axle and a tridem axle and used for hauling coal, logs, and pulpwood if such vehicle is of a type of vehicle as was operating in such counties on U.S. Routes 40 or 48 for such purposes on August 1, 1991. (k) Any over-the-road bus, or any vehicle which is regularly and exclusively used as an intrastate public agency transit passenger bus, is excluded from the axle weight limits in paragraphs (c) through (e) of this section until October 1, 2009. Any State that has enforced, in the period beginning October 6, 1992, and ending November 30, 2005, a single axle weight limitation of 20,000 pounds or greater but less than 24,000 pounds may not enforce a single axle weight limit on these vehicles of less than 24,000 lbs. (m) The provisions of paragraphs (b) through (e) of this section shall not apply to the operation, on I-99 between Bedford and Bald Eagle, Pennsylvania, of any vehicle that could legally operate on this highway section before December 29, 1995. (n) Any vehicle subject to this subpart that utilizes an auxiliary power or idle reduction technology unit in order to promote reduction of fuel use and emissions because of engine idling, may be allowed up to an additional 400 lbs. total in gross, axle, tandem, or bridge formula weight limits. (1) To be eligible for this exception, the operator of the vehicle must be able to prove: (i) By written certification, the weight of the APU; and (ii) By demonstration or certification, that the idle reduction technology is fully functional at all times. (2) Certification of the weight of the APU must be available to law enforcement officers if the vehicle is found in violation of applicable weight laws. The additional weight allowed cannot exceed 400 lbs. or the weight certified, whichever is less. [49 FR 23315, June 5, 1984, as amended at 59 FR 30420, June 13, 1994; 60 FR 15214, Mar. 22, 1995; 62 FR 10181, Mar. 5, 1997; 63 FR 70653, Dec. 22, 1998; 72 FR 7748, Feb. 20, 2007]	
§ 658.19 Reasonable access. (a) No State may enact or enforce any law denying reasonable access to vehicles with dimensions authorized by the STAA between the NN and terminals and facilities for food, fuel, repairs, and rest. In addition, no State may enact or enforce any law denying reasonable access between the	As mentioned in Title 49 USC§31114, Access to the Interstate System, and §31111[c] as it relates to vehicle combinations having access to certain facilities, this

Current Statutory Language	Impacts
NN and points of loading and unloading to household goods carriers, motor carriers of passengers, and any truck tractor-semitrailer combination in which the semitrailer has a length not to exceed 28 feet (28.5 feet where allowed pursuant to § 658.13(b)(5) of this part) and which generally operates as part of a vehicle combination described in §§ 658.13(b)(5) and 658.15(a) of this part. (b) All States shall make available to commercial motor vehicle operators information regarding their reasonable access provisions to and from the National Network. (c) Nothing in this section shall be construed as preventing any State or local government from imposing any reasonable restriction, based on safety considerations, on access to points of loading and unloading by any truck tractor-semitrailer combination in which the semitrailer has a length not to exceed 281/2 feet and which generally operates as part of a vehicle combination described in §§ 658.13(b)(5) and 658.15(a). (d) No State may enact or enforce any law denying access within 1 road-mile from the National Network using the most reasonable and practicable route available except for specific safety reasons on individual routes. (e) Approval of access for specific vehicles on any individual route applies to all vehicles of the same type regardless of ownership. Distinctions between vehicle types shall be based only on significant, substantial differences in their operating characteristics. (f) Blanket restrictions on 102-inch wide vehicles may not be imposed. (g) Vehicle dimension limits shall not be more restrictive than Federal requirements. (h) States shall ensure compliance with the requirements of this section for roads under the jurisdiction of local units of government. (i) (1) Except in those States in which State law authorizes the operation of STAA-dimensioned vehicles on all public roads and highways, all States shall have an access review process that provides for the review of requests for access from the National Network. (2) State access review processes shall provide for: (i) One or more of the following: (A) An analysis of the proposed access routes using observations or other data obtained from the operation of test vehicles over the routes;	section may be impacted if the alternative truck configurations included in the study are adopted.

Current Statutory Language	**Impacts**
(B) An analysis of the proposed access routes by application of vehicle templates to plans of the routes; (C) A general provision for allowing access, without requiring a request, for commercial motor vehicles with semitrailers with a kingpin distance of 41 feet or less (measured from the kingpin to the center of the rear axle, if single, or the center of a group of rear axles). State safety analyses may be conducted on individual routes if warranted; and (ii) All of the following: (A) The denial of access to terminals and services only on the basis of safety and engineering analysis of the access route. (B) The automatic approval of an access request if not acted upon within 90 days of receipt by the State. This provision shall become effective no later than 12 months following the effective date of this rule unless an extension is requested by the State and approved by FHWA. (C) The denial of access for any 102-inch wide vehicles only on the basis of the characteristics of specific routes, in particular significant deficiencies in lane width. (j) (1) Each State shall submit its access provisions to FHWA for approval within 6 months after June 1, 1990. In those States in which State law authorizes the operation of STAA-dimensioned vehicles on all public roads and highways, no submission or approval under this paragraph is required. If, in the future, such a State changes its authorizing legislation and restricts the operation of STAA-dimensioned vehicles, then compliance with these provisions will be necessary. (2) The FHWA will review the access provisions as submitted by each State subject to the provisions in paragraph (j)(1) and approve those that are in compliance with the requirements of this section. The FHWA may, at a State's request, approve State provisions that differ from the requirements of this section if FHWA determines that they provide reasonable access for STAA-dimensioned vehicles and do not impose an unreasonable burden on motor freight carriers, shippers and receivers and service facility operators. (3) Any State that does not have FHWA approved access provisions in effect within 1 year after June 1, 1990 shall follow the requirements and the criteria set forth in this section and section 658.5 and 658.19 for determining access for STAA-dimensioned vehicles to terminals and services. The FHWA may approve a State's request for a time extension if it is received by FHWA at least 1 month before	

Current Statutory Language	Impacts
the end of the 1 year period. [53 FR 12149, Apr. 13, 1988, as amended at 55 FR 22763, June 1, 1990; 59 FR 30420, June 13, 1994]	
§ 658.23 LCV freeze; cargo-carrying unit freeze. (a) (1) Except as otherwise provided in this section and except for tow trucks with vehicles in tow, a State may allow the operation of LCV's on the Interstate System only as listed in appendix C to this part. (2) Except as otherwise provided in this section, a State may not allow the operation on the NN of any CMV combination with two or more cargo-carrying units (not including the truck tractor) whose cargo-carrying units exceed: (i) The maximum combination trailer, semitrailer, or other type of length limitation authorized by State law or regulation of that State on or before June 1, 1991; or (ii) The length of the cargo-carrying units of those CMV combinations, by specific configuration, in actual, lawful operation on a regular or periodic basis (including continuing seasonal operation) in that State on or before June 1, 1991, as listed in appendix C to this part. (b) Notwithstanding paragraph (a)(2) of this section, the following CMV combinations with two or more cargo-carrying units may operate on the NN. (1) Truck tractor-semitrailer-trailer and truck tractor-semitrailer-semitrailer combinations with a maximum length of the individual cargo units of 28.5 feet or less. (2) Vehicles described in § 658.13(e) and (g). (3) Truck-trailer and truck-semitrailer combinations with an overall length of 65 feet or less. (4) Maxi-cubes. (5) Tow trucks with vehicles in tow. (c) For specific safety purposes and road construction, a State may make minor adjustments of a temporary and emergency nature to route designation and vehicle operating restrictions applicable to combinations subject to 23 U.S.C. 127(d) and 49 U.S.C. 31112 and in effect on June 1, 1991 (July 6, 1991, for Alaska). Minor adjustments which last 30 days or less may be made without notifying the FHWA. Minor adjustments which exceed 30 days require approval of the FHWA. When such adjustments are needed, a State must submit to the FHWA, by the end of the 30th day, a written description of the emergency, the date on which it began, and the date on which it is expected to conclude. If the adjustment involves alternate route designations, the State	This section would be impacted if the current “freeze” applied to triple trailer combinations is lifted. Specific reference would need to be made for those configurations in this section. Section (b)(1) would require a modification if twin 33-foot doubles are adopted with STAA mobility rights. The length specified in paragraph (b)(3) would be impacted and would need to be re-evaluated to determine if it remains adequate or if it would be in need of modification. The process for making adjustments in routing in paragraph (c) is still relevant for all LCV operations, even the new, heavier configurations that may have access similar to all other STAA vehicles. No impact is noted on the routing and access provisions as pertaining to reasonable access route modifications being allowed on a safety basis. The process for such modifications to reasonable access routes based on safety considerations demonstrated by the States and provisions for making modifications remain relevant.

Current Statutory Language	Impacts
shall describe the new route on which vehicles otherwise subject to the freeze imposed by 23 U.S.C. 127(d) and 49 U.S.C. 31112 are allowed to operate. To the extent possible, the geometric and pavement design characteristics of the alternate route should be equivalent to those of the highway section which is temporarily unavailable. If the adjustment involves vehicle operating restrictions, the State shall list the restrictions that have been removed or modified. If the adjustment is approved, the FHWA will publish the notice of adjustment, with an expiration date, in the Federal Register. Requests for extension of time beyond the originally established conclusion date shall be subject to the same approval and publications process as the original request. If upon consultation with the FHWA a decision is reached that minor adjustments made by a State are not legitimately attributable to road or bridge construction or safety, the FHWA will inform the State, and the original conditions of the freeze must be reimposed immediately. Failure to do so may subject the State to a penalty pursuant to 23 U.S.C. 141. (d) A State may issue a permit authorizing a CMV to transport an overlength nondivisible load on two or more cargo-carrying units on the NN without regard to the restrictions in § 658.23(a)(2). (e) States further restricting or prohibiting the operation of vehicles subject to 23 U.S.C. 127(d) and 49 U.S.C. 31112 after June 1, 1991, shall notify the FHWA within 30 days after the restriction is effective. The FHWA will publish the restriction in the Federal Register as an amendment to appendix C to this part. Failure to provide such notification may subject the State to a penalty pursuant to 23 U.S.C. 141. (f) The Federal Highway Administrator, on his or her own motion or upon a request by any person (including a State), shall review the information set forth in appendix C to this part. If the Administrator determines there is cause to believe that a mistake was made in the accuracy of the information contained in appendix C to this part, the Administrator shall commence a proceeding to determine whether the information published should be corrected. If the Administrator determines that there is a mistake in the accuracy of the information contained in appendix C to this part, the Administrator shall publish in the Federal Register the appropriate corrections to reflect that determination. [59 FR 30420, June 13, 1994, as amended at 60 FR 15214, Mar. 22, 1995; 62 FR 10181, Mar. 5, 1997; 72 FR 7748, Feb. 20, 2007]	

Current Statutory Language	**Impacts**
Appendix A - National Network—Federally-Designated Routes -	No impacts noted.
Appendix B – Grandfathered Semitrailer Lengths	No impacts noted.
Appendix C - Trucks Over 80,000 Pounds on the Interstate System and Trucks Over STAA Lengths on the National Network	Significant impacts to this Appendix are noted. This appendix will need to be substantially updated if Congress adopts vehicles heavier than the vehicles that are legal to operate under current Federal limits. If operations are allowed in all States but restricted to certain roadways, those roadways and other pertinent rules for each state could be listed in this Appendix.

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APPENDIX E. DATA GATHERING INSTRUMENT FOR INCREMENTAL TIME TO ENFORCE TRUCK WEIGHTS

This appendix provides the data gathering instrument and associated instructions used to determine the potential incremental time to enforce truck weights for the alternative truck configurations using various types of scales.

Instructions:

The USDOT study team is gathering data concerning the potential incremental time (and cost) required to enforce truck weights for the six alternative configurations being considered as part of the 2014 CTSW Study. In the table that follows, please estimate the amount of time required to weigh the base case configuration (Base Case A) for each of the scale types listed. In the next three rows, please indicate by clicking on the box whether or not (“yes” or “no”) you would expect there to be an impact on the time to enforce truck weight on the alternative configuration shown compared to the base case configuration. If you answer “yes,” please estimate a magnitude of this incremental impact (e.g., minutes/axle or minutes/truck).

The table also requests the same type of information, except for a different base case configuration (Base Case B) and three different 2014 CTSW Study alternative truck configurations. Please provide any explanatory comments and note any additional types of costs (e.g., cost to re-program WIM screening algorithms) in the space below the table.

Data Collection form to Estimate Weighing Time for Multiple-Trailer Trucks by Scale Type

Alternative Configuration comparisons	Portable scale	Semi-portable scale	Static weigh scale (weighs axle groups)	Static weigh bridge (weighs full vehicle)	WIM (including WIM at a virtual weigh scale)
Base Case A:  3-S2 @ 80K lb (53')	Est. weighing time? Click here to enter text.	Est. weighing time? Click here to enter text.	Est. weighing time? Click here to enter text.	Est. weighing time? Click here to enter text.	Est. weighing time? Click here to enter text.
Base Case A vs.  3-S2 @ 88K lb (53')	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.
Base Case A vs.  3-S3 @ 91K lb (53')	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.
Base Case A vs.  3-S3 @ 97K lb (53')	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.
Base Case B:  2-S1-2 @ 80K lb (2 x 28.5')	Est. weighing time? Click here to enter text.	Est. weighing time? Click here to enter text.	Est. weighing time? Click here to enter text.	Est. weighing time? Click here to enter text.	Est. weighing time? Click here to enter text.
Base Case B vs.  2-S1-2 @ 80K lb (2 x 33')	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.
Base Case B vs.  2-S1-2-2 @ 105K lb (3 x 28.5')	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.
Base Case B vs.  3-S2-2-2 @ 129K lb (3 x 28.5')	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.	Impact? Y ☐ N ☐ Magnitude? Click here to enter text.

Additional comments: