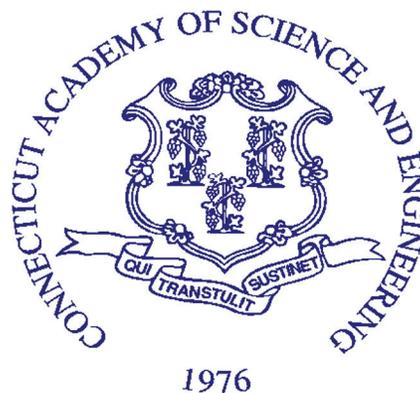


**INNOVATIVE TECHNOLOGY
DEPLOYMENT: DEVELOPMENT OF A
VIRTUAL SCREENING FACILITY
PILOT PROJECT FOR CONNECTICUT'S
COMMERCIAL VEHICLE
ENFORCEMENT PROGRAM**

NOVEMBER 2017

A REPORT BY

**THE CONNECTICUT
ACADEMY OF SCIENCE
AND ENGINEERING**



FOR

**THE CONNECTICUT DEPARTMENT OF
TRANSPORTATION
THE CONNECTICUT DEPARTMENT OF
MOTOR VEHICLES**

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ORIGIN OF INQUIRY:	THE CONNECTICUT DEPARTMENT OF TRANSPORTATION THE CONNECTICUT DEPARTMENT OF MOTOR VEHICLES
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This study was initiated at the request of the Connecticut Department of Transportation and the Connecticut Department of Motor Vehicles on October 18, 2016. The project was conducted by an Academy Study Committee with the support of BGM Consulting, with Barry Mason serving as Study Manager and David Pines, PhD, serving as a Study Advisor. The content of this report lies within the province of the Academy's Transportation Systems Technical Board. The report has been reviewed on behalf of the Academy's Council by Academy Members John DeWolf, PhD, and John N. Ivan, PhD. Martha Sherman, the Academy's Managing Editor, edited the report. The report is hereby released with the approval of the Academy Council.

Richard H. Strauss
Executive Director

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Connecticut Department of Transportation, Connecticut Department of Motor Vehicles or the Federal Highway Administration. The report does not constitute a standard, specification, or regulation.

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INNOVATIVE TECHNOLOGY DEPLOYMENT: DEVELOPMENT OF A VIRTUAL SCREENING
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GLOSSARY

ADT	Average Daily Traffic
ASTM	American Society for Testing and Materials
AVI	Automatic Vehicle Identification (i.e., license plate readers, USDOT number readers, commercial vehicle transponder readers, cellular applications)
CCTV	Closed-circuit Television
CSP	Division of State Police, Connecticut Department of Emergency Services and Public Protection
CTDMV	Connecticut Department of Motor Vehicles
CTDOT	Connecticut Department of Transportation
CV	Commercial Vehicle
CVE	Commercial Vehicle Enforcement
CVEO	Commercial Vehicle Enforcement Officer. A CTDMV or CSP officer with duties and authority that includes commercial vehicle enforcement
CVEF	Commercial Vehicle Enforcement Facility. An operations site where commercial vehicle enforcement is performed. A staffed facility is typically called a weigh station. Enforcement activity may include any or all of the following: weight, size, credentials, driver safety, and commercial vehicle safety. CVEFs may operate part-time or 24/7.
CVISN	Commercial Vehicle Information Systems and Networks Program of the Federal Motor Carrier Administration. As of October 2016 this program was re-designated the Innovative Technology Deployment (ITD) Program. Both CVISN and ITD are used in this report.
CVSA	Commercial Vehicle Safety Alliance, a North American organization focused on CV safety enforcement
Direct Enforcement Site	Location for Commercial Vehicle Enforcement personnel to conduct inspections of trucks, trailers and drivers for weight, size and safety violations
DMS	Dynamic Message Signs
FHWA	Federal Highway Administration, USDOT
Fixed Site	In Connecticut, a fixed site is a direct enforcement site (also known as a Connecticut Weigh Station) that includes static scale and scale house, as well as potentially other enforcement equipment/facilities (low speed ramp WIM [Greenwich, Union] and safety inspection building [Union])
FMCSA	Federal Motor Carrier Safety Administration
GIS	Geographic Information System

Gore	An unpaved area created between the highway mainline and a ramp that merges into or diverges from the mainline
ITD	Innovative Technology Deployment Program (formerly known as CVISN) of FMCSA. The mission of this program is to improve commercial motor vehicle safety (https://www.fmcsa.dot.gov/information-systems/itd/innovative-technology-deployment-itd)
	CTDOT Environmental Permit Coordination Unit
Intelligent Transportation Systems	Advanced information and communications applications to improve road operations and safety through the use of state of the art telecommunications, computers, and other technologies. Examples include WIM, CCTV cameras, and DMS as well as the communications backbone, control, data processing, and data storage equipment.
Level of Inspection (I, II, III, IV, V)	The type of CVE safety inspection conducted. Level I is the most comprehensive; Level V is the least comprehensive. CVSA defines these types of inspections. For full details see: http://cvsa.org/inspections/inspections/all-inspection-levels/
	Federal Emergency Management Agency
MCSAP	Motor Carrier Safety Assistance Program
PreClearance Systems	A method to allow commercial vehicles to bypass a CVEF or VSF as a result of safety and size and weight compliance.
USDOT	US Department of Transportation
VSF	Virtual Screening Facility. An unstaffed facility that provides a CVEO with real-time commercial vehicle information electronically using in-pavement sensors and communications. The intent is to provide data and information for CV screening based on site functionality using a combination of WIM, AVI, over height detection and other equipment at each site.
Weigh Station	A location used to conduct safety inspections and/or weigh commercial vehicles. If a facility has static scale, some level of safety inspection is also typically conducted. These are a subset of CVEFs.
WIM	Weigh-in-Motion System. A WIM is used to weigh commercial vehicles at highway or low speeds using in pavement sensors. WIMs are typically located either on the mainline just upstream of a CVEF, on the entrance ramp to a CVEF (ramp or low speed WIM), and at a VSF.

EXECUTIVE SUMMARY

This study was conducted for the Connecticut Department of Transportation (CTDOT) and the Connecticut Department of Motor Vehicles (CTDMV) by the Connecticut Academy of Science and Engineering (CASE) for the purpose of creating an implementation document for development of a virtual electronic screening (e-screening) and weigh-in-motion (WIM) pilot project.

Additionally, a goal of the analysis is to select virtual screening functionalities that are matched with enforcement strategies and provide flexibility taking into consideration factors such as new technologies, and changing enforcement strategies and traffic volumes over time. The performance of the functions needs to be the focus, using the technology to support those functions. Desired outcomes include

- positively changing the behavior of motor carriers/commercial vehicles and drivers that violate state and federal regulatory requirements;
- protecting the state's highway infrastructure;
- enabling motor carriers/commercial vehicles and drivers operating in a safe and legal manner to bypass inspection stations thus improving mobility by saving time, fuel and operational costs; and
- providing enhanced motor vehicle safety for the public.

OVERVIEW

Study research methods included:

- Review and analysis of current and relevant literature and best practices of selected states
- Project meetings for Research Team discussion on various study issues with CTDOT/CTDMV staff.
- Site visits including a tour of Connecticut weigh stations and potential Virtual Screening Facility (VSF) sites and a tour of weigh stations utilizing e-screening technologies and functionalities in Florida.
- Mobile enforcement observation ride-along at the I-91 VSF site
- Guest Speaker Presentations from experts who provided presentations on study issues to the CASE Study Committee and agency study contacts. The data and information presented has been incorporated into the study report as appropriate. Guest speaker presentation information is available electronically, as noted in Appendix C.

The study report includes the following sections: Background, Introduction, Feasibility Analysis, Proven Functionalities and Technologies, Appropriate Technologies for the VSF Pilot Project, Smart Roadside Initiative Technologies Deployed by States, List of Technological

Components and Data Modules, Implementation Time frame and Cost Estimate, and Recommendations and Concluding Remarks.

BRIEF STATEMENT OF PRIMARY CONCLUSION

Investment in the deployment of innovative technologies to screen commercial vehicles and drivers for weight and safety inspection has the potential to improve the effectiveness of Connecticut's commercial vehicle enforcement program and achieve outcomes including improved safety, highway preservation, and increased mobility of commercial vehicles traveling in Connecticut.

Virtual Screening Facilities (VSFs) and weigh stations with enhanced screening functionalities will enable enforcement officers to focus enforcement operations on those commercial vehicles most likely to be in violation of state and federal weight, size, and safety laws, while providing those in compliance with increased mobility by allowing them to bypass enforcement activities. Importantly, analysis of the 24/7 data collected from these sites provides the opportunity to strategically design enforcement strategies to maximize enforcement effectiveness.

Performance measures used for administrative purposes and required by state statute for assessing the effectiveness the commercial vehicle enforcement program should be based on and aligned with programmatic objectives and outcomes. Metrics used to assess success in achieving desired outcomes should include measures related to improving safety, highway preservation, and mobility.

RECOMMENDATIONS

This study presents an implementation plan for development of a pilot VSF for use by CTDOT/CTDMV. The pilot VSF will be used to test various technologies to determine their value in enhancing commercial vehicle size, weight and safety enforcement in Connecticut. Three sites were analyzed for selection as the pilot project. Based on the analyses, the I-91 SB at Route 510 site was selected as the pilot VSF project by CTDOT/CTDMV.

The study recommendations are shown in two categories: those related to the VSF pilot project, and additional recommendations regarding the commercial vehicle enforcement program based on the research and analyses conducted throughout this study.

VSF Pilot Project

Based on the analyses conducted, CTDMV/CTDOT should plan, design, construct and operate a pilot VSF at the proposed site for the purpose of testing VSF technologies for potential future use at additional VSF sites and existing weigh stations. The following suggestions are offered for consideration by CTDOT and CTDMV:

- CTDMV/CTDOT: Evaluate the pilot VSF through the collection and analyses of data using the proposed performance measures
 - o Review the proposed performance measures identified in Chapter 7 with the VSF

contractor and revise as necessary to assure that data collected and reported will provide system analyses needed for decisions on deployment of additional VSFs.

- o Report on the impact of the pilot VSF based on the performance measures.
- o Use results of the pilot project for planning additional deployments of VSF technologies and functionalities.
- CTDOT: Utilize traffic data for real time traffic management and future planning needs
- CTDMV/CTDOT/CSP: Establish an interagency Memorandum of Understanding (MOU) to formalize responsibilities of CTDMV/CTDOT and CSP for the planning, design, construction and operation and reporting for the pilot VSF project as part of an interagency MOU for formalizing overall responsibilities for the Commercial Vehicle Enforcement Program (see Additional Recommendations).

Additional Recommendations

The following additional recommendations are included as additional opportunities for consideration by CTDMV/CTDOT to improve and enhance the state's commercial vehicle enforcement program:

- Establish an interagency MOU between CTDMV, CTDOT and CSP to create a multi-agency working group to formalize each agency's responsibilities for the Commercial Vehicle Enforcement Program for the purpose of collaboration, cooperation, and coordination to achieve the program's overall size, weight, and safety goals. Suggested responsibilities of the working group include:
 - o Planning, operation, and management of the Commercial Vehicle Enforcement Program and the facilities that support the program – weigh stations and VSFs. Also, development of a program budget and annual reporting (budget vs. actual) for enforcement operations, maintenance of facilities and systems, and capital projects.
 - o Development of a strategic plan for continuous improvement of the Commercial Vehicle Enforcement Program, including but not limited to
 - ◆ goals/strategies/outcomes;
 - ◆ feasibility evaluation for siting additional VSFs or other facilities;
 - ◆ design and construction guidelines for development of additional VSFs and upgrading of existing weigh stations;
 - ◆ performance measures for operation of the program; include systemic success measures (program outcomes: progress in changing behavior such as accidents, injuries, and fatalities involving commercial vehicles, and pavement preservation); and
 - ◆ reporting on performance measures, and other factors such as VSF system operation.

- Oversight for the development of the pilot VSF, other VSFs, and use of VSF technologies and functionalities to enhance existing weigh stations.
- The following provides guidance for prioritizing the development and installation of additional VSFs, and VSF technologies and functionalities at existing weigh stations:
 - Table ES.1 shows the annual average percentage of overweight citations issued at each of the existing weigh stations for fiscal years 2009 – 2016, calculated by dividing the annual average number of overweight citations issued by the average total number of commercial vehicles weighed. This information provides a foundation for considering the need for additional deployments of VSF technologies. This data shows that the percentage of commercial vehicles issued overweight citations is very low as compared with the number of vehicles weighed for all weigh stations in Connecticut. The results of pilot VSF enforcement operations will be useful in determining the value of screening commercial vehicles for weight and safety inspection in Connecticut. As has been shown in other states, screening has been effective in improving commercial vehicle enforcement effectiveness.

TABLE ES.1: ANNUAL AVERAGE PERCENTAGE OF OVERWEIGHT CITATIONS ISSUED AT EXISTING WEIGH STATIONS (FY2009 – FY2016)

Weigh Station (ordered by percentage of citations issued)	Percentage of Overweight Citations Issued	Overweight Citations	Total CVs Weighed
Middletown (I-91 NB)	1.36%	455	33,397 (Static Scale Only)
Greenwich (I-95 NB)	1.0%	1,660	165,609 (WIM & Static Scale)
Waterford (I-95 SB)	0.93%	133	14,337 (Static Scale Only)
Danbury (I-84 EB)	0.84%	505	59,811 (Static Scale Only)
Waterford (I-95 NB)	0.56%	125	22,239 (Static Scale Only)
Union (I-84 WB)	0.12%	316	262,871 (WIM & Static Scale)
<p>Notes:</p> <ol style="list-style-type: none"> 1. Data shown are annual averages for the period of FY2009 – FY2016 2. Static Scale Only: CVs are weighed only on static scales at the Danbury, Middletown, and Waterford Weigh Stations 3. WIM & Static Scale: CVs are weighed on ramp WIM and static scales at Greenwich and Union Weigh Stations 			

- If it is determined that the pilot VSF project was successful in improving commercial vehicle enforcement effectiveness, it is suggested that testing VSF technologies and functionalities at one of the state's existing weigh stations should be the next priority.
 - ◆ It is suggested that the Greenwich Weigh Station (I-95 NB) be considered as the next site to test VSF technologies. This site has the greatest amount of commercial vehicle traffic of all of the state's weigh stations. Typically, when the weigh station is open, commercial vehicles entering the weigh station quickly queue onto the mainline resulting in frequent closing and opening

- of the station. This VSF installation would include a mainline sorting system to improve safety and effectiveness and enable the manually operated ramp WIM to be decommissioned. It is noted that this installation requires coordination with New York State for installation of signage in New York directing commercial vehicles to use the right lane only.
- ◆ If installation of VSF technologies at the Greenwich Weigh Station is not possible, then the Middletown Weigh Station (I-91 NB) should be considered as the next test site. As shown in Table ES.1, the Middletown Weigh Station has the highest annual average percentage of overweight citations issued compared to the total number of commercial vehicles weighed. This section of I-91 NB also has a high level of commercial vehicle traffic, including both intrastate and interstate. This VSF installation would include a mainline sorting system to improve safety and effectiveness. This project could potentially be considered as part of the CTDOT proposed I-91/I-691 project.
 - Considerations for prioritizing development of additional VSF installations based on the results of the pilot VSF project and an initial weigh station VSF enhancement project are as follows.
 - ◆ Two VSF sites were considered for the pilot project and are potential sites for development of additional VSFs.
 - I-95 SB at the Rhode Island border. This site is just past Exit 93 with the Mystic/North Stonington Rest Area identified to serve as the primary direct enforcement area, along with the I-95 Southbound Waterford Weigh Station being available as a secondary direct enforcement site. An advantage of deployment of a VSF at this location is that enforcement presence would be available before commercial vehicles travel over the Gold Star Bridge in Groton.
 - I-395 SB in the vicinity of Plainfield Service Plaza (identified to serve as the primary direct enforcement area) and U.S. Route 6. This site is currently not protected with a weigh station, with commercial vehicle enforcement only provided through periodic mobile enforcement. Installation of a VSF site would provide enforcement coverage for southbound commercial vehicle traffic entering the state from Massachusetts and Rhode Island, and may serve to reduce the number of vehicles that use I-395 southbound in an effort to bypass the Union Weigh Station on I-84 westbound.
 - ◆ Connecticut's weigh stations, in addition to the Greenwich Weigh Station and the Middletown Weigh Station previously discussed.
 - Danbury Weigh Station (I-84 EB). This weigh station is very close to the New York State border. It is co-located in a rest area used by the public. A VSF installed at this location to support enforcement at the weigh station would need to be located in New York State. Agreement with New York State would be needed. An alternative could be the development of a VSF as part of the I-84/Route 7 project, pending identification of an acceptable site to replace the Danbury Weigh Station.

- Union Weigh Station (I-84 WB). This weigh station is close to the Massachusetts border. Currently, a ramp WIM is used for screening vehicles to be weighed on a static scale. A mainline WIM is installed at this site, but it is not operational at this time. VSF technologies would be installed to enhance enforcement, including replacement of the mainline WIM and decommissioning of the ramp WIM. Additionally, installation of a VSF at this location to enhance enforcement for I-84 EB should be considered, with the weigh station being used as the primary direct enforcement area.
 - Waterford Weigh Station (I-95 NB). This weigh station has limited space for enforcement. A VSF installed at this location with screening functionalities would support enforcement and improve the effectiveness of the weigh station. The proposed I-95 expansion project in southeastern Connecticut may impact the future of this weigh station, and could be a consideration in a decision regarding investment in improvements.
 - Waterford Weigh Station (I-95 SB). A decision on enhancing this weigh station with VSF functionalities should be based on the installation of the proposed VSF on I-95 SB at the Rhode Island border. If this VSF is developed, then this weigh station would serve as a secondary direct enforcement site for the VSF. However, similar to the Waterford Weigh Station NB, the proposed I-95 expansion project may impact a decision to invest in improvements at this weigh station.
- Utilize CTDOT WIM planning data for commercial vehicle enforcement and data analysis.
 - o Provide access to planning WIM site data in real-time for CTDMV/CSP commercial vehicle enforcement
 - o Use WIM planning data and VSF data for trend analysis of a systemic performance measure on the weights of commercial vehicles traveling on Connecticut highways.
 - Consideration of additional functionalities to support commercial vehicle enforcement include:
 - o Development of E-permits and integration into the VSF system.
 - o Integration of hazmat readers into VSF sites that are upstream from a weigh station or a VSF that uses a sorting strategy. Hazmat readers currently are effective if used in the right lane only.
 - o Observation cameras to monitor bypass routes around weigh stations and VSFs. These cameras would provide enforcement staff with the capability to remotely monitor bypass routes with dispatch for enforcement only when necessary.
 - o Use of a self-contained mobile enforcement trailer, similar to that used by

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Massachusetts and Rhode Island, that provides VSF functionalities for mobile enforcement use on interstates and secondary roads throughout the state.

- Add functionality for Amber Alerts at VSF sites. This requires an additional LPR in each lane to read rear license plates.
- Collaborate with other states to enhance the effectiveness of Connecticut's Commercial Vehicle Enforcement Program and regional commercial vehicle enforcement.
 - o Align commercial vehicle codes, where possible, to minimize conflicts.
 - o Data sharing to provide adjacent states with analysis of VSF data and Connecticut's enforcement results, including such information by state registration. Secure this same information from other collaborating states, if available.
 - o Development of facilities at state borders.
- Conduct an analysis of the Judicial Branch's disposition of commercial vehicle and driver citations issued by enforcement officers
 - o Explore opportunities to improve the percentage of guilty verdicts and fine collections through a review of commercial vehicle enforcement procedures and processes, judicial system procedures and processes, and the fine structure.
- Consider legislative initiatives to amend state statutes related to weigh station staffing and reporting requirements.
 - o *CGS Chapter 248, § 270c [1-4]: Official Weighing Areas. Staffing Requirements*

This statute mandates weigh station shift staffing requirements. It is suggested that legislatively mandated staffing requirements should be eliminated and the balance of this statute should be revised to enable staffing flexibility that will provide for more strategic randomized enforcement strategy with a goal of improving the effectiveness of the commercial vehicle enforcement program for weigh station, VSF, and mobile enforcement.

- o *CGS Chapter 248, § 270f: Weigh Station Logs*

Revise legislatively mandated semi-annual weigh station reporting requirements to be consistent with the established performance measures for the commercial vehicle enforcement program.

- o *CGS Chapter 248, § 270e: Program to Implement Regularly Scheduled and Enforced Hours of Operation for Weigh Stations*

Review and revise legislatively mandated annual planned enforcement program reporting requirements to ensure that required reporting information allows for random scheduling of weigh station staffing.

CONCLUDING REMARKS

The development of a VSF involves design, construction and installation of equipment typical of many highway projects. However, the integration of various VSF functions adds complexity to the development and use of a VSF for real-time commercial vehicle enforcement and highway planning.

The integrator is the project partner with the responsibility to assure that the information collected at the VSF site is analyzed seamlessly in real time to provide enforcement officers with results needed to screen commercial vehicles for weight, size, and safety inspection. The speed, accuracy, and ease of use of the information provided are key elements of a successful VSF. Additionally, a critical element of the integrator's system is the ability to analyze 24/7 VSF data collected to enable strategic development and refinement of enforcement strategies.

1.0 BACKGROUND

The primary objectives of commercial vehicle enforcement are to ensure commercial vehicle compliance, preservation of state highways and bridges, and safety of the motoring public. Standard commercial vehicle enforcement services include motor carrier compliance reviews, commercial vehicle and commercial driver safety inspections, size and weight enforcement, and mobile traffic safety enforcement.

The US Department of Transportation (USDOT), Federal Highway Administration (FHWA) 23 CFR 657 specifies the requirements for states to develop and maintain a commercial vehicle enforcement program, including "Sec. 657.9 Formulation of a plan for enforcement" as follows:

(a) Each State shall develop a plan for the maintenance of an effective enforcement process. The plan shall describe the procedures, resources, and facilities which the State intends to devote to the enforcement of its vehicle size and weight laws. Each State plan must be accepted by the FHWA and will then serve as a basis by which the annual certification of enforcement will be judged for adequacy.

(b) The plan shall discuss the following subjects:

(1) Facilities and resources. (i) No program shall be approved which does not utilize a combination of at least two of the following listed devices to deter evasion of size and weight measurement in sufficient quantity to cover the FA [federal aid highway] system: fixed platform scales; portable wheel weigher scales; semiportable or ramp scales; WIM equipment.

(ii) Staff assigned to the program, identified by specific agency. Where more than one State agency has weight enforcement responsibility, the lead agency should be indicated.

(2) Practices and procedures. (i) Proposed plan of operation, including geographical coverage and hours of operation in general terms.

(ii) Policy and practices with respect to overweight violators, including off-loading requirements for divisible loads. In those States in which off-loading is mandatory by law, an administrative variance from the legal requirement shall be fully explained. In those States in which off-loading is permissive administrative guidelines shall be included.

(iii) Policy and practices with respect to penalties, including those for repeated violations. Administrative directives, booklets or other written criteria shall be made part of the plan submission.

(iv) Policy and practices with respect to special permits for overweight. Administrative directives, booklets or other written criteria shall be made part of the plan submission.

(3) Updating. Modification and/or additions to the plan based on experience and new developments in the enforcement program. It is recognized that the plan is not static and that changes may be required to meet changing needs.

Also, an FHWA "Program Review: FY2015 Connecticut Vehicle Size and Weight Enforcement Program" (2016) report summarized the importance of commercial vehicle weight compliance, as follows:

The impact of excessive vehicle weight on the nation's road system is well documented. In addition to imposing potential damage to bridges not designed to carry today's very heavy

vehicles, numerous State and national studies have shown that vehicle weight has a direct impact on roadway pavement damage. In fact, the level of damage as weight increases follows an exponential (fourth power) curve [Figure 1.0] once vehicle weight starts to exceed the current statutory weight limits. A five axle 80,000-pound semi-trailer truck causes pavement distress equivalent to that caused by about 9,600 cars.



FIGURE 1.0. GRAPH DEPICTING PAVEMENT DAMAGE (SOURCE: AASHTO ROAD TEST, GENERALIZED 4TH POWER LAW, AS REFERENCED BY PROGRAM REVIEW: FY2015 CONNECTICUT VEHICLE SIZE AND WEIGHT ENFORCEMENT PROGRAM” (2016) REPORT; PAGE 3)

Congress recognized the danger of overloaded trucks on the nation’s highway system and passed laws to restrict weights on the Interstate System, which every State must support. In an unusual move, the legislation included a specific financial sanction on any State found to not be adequately enforcing Federal weight laws--a loss of 10% of the State’s Federal apportionments.

Further, the website of the Federal Motor Carrier Safety Administration (FMCSA) includes an overview of the Motor Carrier Safety Assistance Program (MCSAP)¹, a federal grant program that provides financial assistance to states to reduce the number and severity of crashes and hazardous materials incidents involving commercial motor vehicles (CMV).

The goal of the MCSAP is to reduce CMV-involved crashes, fatalities, and injuries through consistent, uniform, and effective CMV safety programs. Investing grant monies in appropriate safety programs increases the likelihood that safety defects, driver deficiencies, and unsafe motor carrier practices are detected and corrected before they become contributing factors to crashes. The MCSAP area includes the following tools that can be used to assist states in developing and monitoring their Commercial Vehicle Safety Plan (CVSP).

- *The State Quarterly Report and CVSP Data Dashboard is a tool that presents quarterly updated safety data to assist states with preparing their MCSAP Formula Grant Quarterly Reports and monitoring MCSAP-funded activities identified in their*

1 FMCSA web link: <https://ai.fmcsa.dot.gov/StatePrograms/Home.aspx>

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CVSP. Note: The Data Dashboard presents all safety data reported to FMCSA's Motor Carrier Management Information System (MCMIS) regardless of the funding source.

- *The **Electronic Commercial Vehicle Safety Plan (eCVSP)** tool is a standardized online template to create, edit, share, and submit State MCSAP Partners eCVSPs.*
- *The **CVSP Toolkit** provides FMCSA and State Enforcement Users the ability to customize data reports to assist in the development of their CVSP.*
- *The **State Safety Performance Measures (SSPMs)** is a tool designed to assist states with identifying commercial motor vehicle safety problem areas and corresponding safety objectives. Two measures have been developed: Domiciled Carrier Safety and Operating Carrier Safety. These measures are produced by aggregating carrier data in the Safety Measurement System (SMS) for the seven Behavior Analysis Safety Improvement Categories, or BASICS.*
- *The **State Data Summary** report provides an overview of select state safety data, including Active Carriers and SMS Summary results, large truck and bus crash involvements, Enforcement Programs data (i.e., roadside inspection, traffic enforcement, and reviews data), and additional information relating to the State Safety Data Quality (SSDQ) evaluation.*

Inspections of vehicles and drivers at roadside and fixed facilities are the primary service used to collect the needed data to feed and support this MCSAP program. Roadside inspections are examinations of commercial motor vehicles and/or drivers by (MCSAP inspectors. MCSAP inspectors conduct roadside inspections on commercial motor vehicles and drivers to check that they are in compliance with the Federal Motor Carrier Safety Regulations (FMCSRs) and/or Hazardous Materials Regulations (HMRs). If an inspection results in serious violations, the driver will be issued a driver or vehicle Out-of-Service Order. These violations must be corrected before the driver or vehicle can return to service.

Historically, the enforcement process for screening motor carriers/commercial vehicles and direct enforcement of commercial vehicles and drivers typically relied on officer experience and judgment. Direct enforcement operations are accomplished through use of mobile enforcement and at weigh stations, and ports of entry. More recently, technological applications have provided new approaches, including virtual screening facilities (VSFs) as described in Section 2.0, that are now frequently used to enhance commercial vehicle enforcement by screening motor carriers/commercial vehicles and drivers.

Additionally, data and information including pavement design, highway maintenance and rehabilitation, and freight planning and programming gathered through commercial vehicle e-screening operations can be utilized for transportation infrastructure decision-making and budgeting.

2.0 INTRODUCTION

This study was conducted for the Connecticut Department of Transportation (CTDOT) and the Connecticut Department of Motor Vehicles (CTDMV) by the Connecticut Academy of Science and Engineering (CASE) for the purpose of creating an implementation document for development and deployment of a virtual electronic screening (e-screening) and weigh-in-motion (WIM) pilot project.

Annually, millions of commercial vehicles move freight throughout Connecticut, an essential component of the commodity delivery system that supplies Connecticut, New England and other parts of the United States. Also, goods movements inbound and outbound from Connecticut are a foundation of the state's overall economy. Sustaining freight mobility, ensuring the safety of commercial and passenger vehicles, and preserving the state's highway infrastructure are key priorities. The CTDOT and CTDMV share similar goals and missions that supporting these overarching goals. The intersection of these priorities is in the collection and analysis of roadside real time traffic data for CTDOT planning, CTDMV commercial vehicle enforcement screening, and overall public safety.

CTDMV's and CTDOT's goal is to utilize state enforcement resources in the most efficient manner possible. The majority of motor carriers operate safely and legally. Many state and federal entities are interested in rewarding motor carriers by allowing those with good safety records to bypass commercial vehicle enforcement sites and inspections, while focusing enforcement resources only on those motor carriers that are not operating safely and/or legally.

A 2009 Federal Highway Administration (FHWA) report² describes the concept of a virtual screening facility, also known as a virtual weigh station, as follows:

...the concept of 'virtual weigh stations' is to develop and deploy automated tools at the roadside capable of conducting measurements, verifications, and certifications traditionally conducted manually at fixed weigh stations...

A virtual weigh station (VWS) is an enforcement facility that does not require continuous staffing and is monitored from another location.³ The virtual weigh station concept is very flexible. While there is a minimum set of functionality/technology that must be deployed in association with a VWS, states can customize their VWS deployments to meet their specific functional needs (e.g., focus exclusively on truck size and weight issues, expand focus to include safety and credentialing regulations), operational environment (e.g., typical weather conditions, physical space, terrain), and communication infrastructure (e.g., presence of communication infrastructure at site, presence of power at site).

Typically, VSFs include some or all of the following technologies with related functionalities:

² Concept of Operations for Virtual Weigh Station; Cambridge Systematics, Inc. (2009)

³ Technology Deployment Challenges and Guidelines on the Use of Weigh-in-Motion in Roadside Enforcement, submitted by Cambridge Systematics to the Federal Highway Administration, April 2009, as part of the Truck Size and Weight Enforcement Technology Project, page 12

- License Plate Reader (LPR) and USDOT Number Reader for automatic vehicle identification (AVI)
- WIM system to weigh a vehicle at highway operating speeds for screening commercial vehicles to be weighed on static or portable scales
- Camera for capturing identification photos of commercial vehicles that are then matched with AVI information, including vehicle size.
- Data integration systems to match VSF-collected data with safety records and information from other sources

VSF technologies/functionalities are used to supplement and support direct enforcement operations conducted through mobile enforcement operations, and at weigh stations or ports of entry. Figure 2.0 depicts a typical VSF facility that includes most of the functionalities expected to be included in the pilot project.

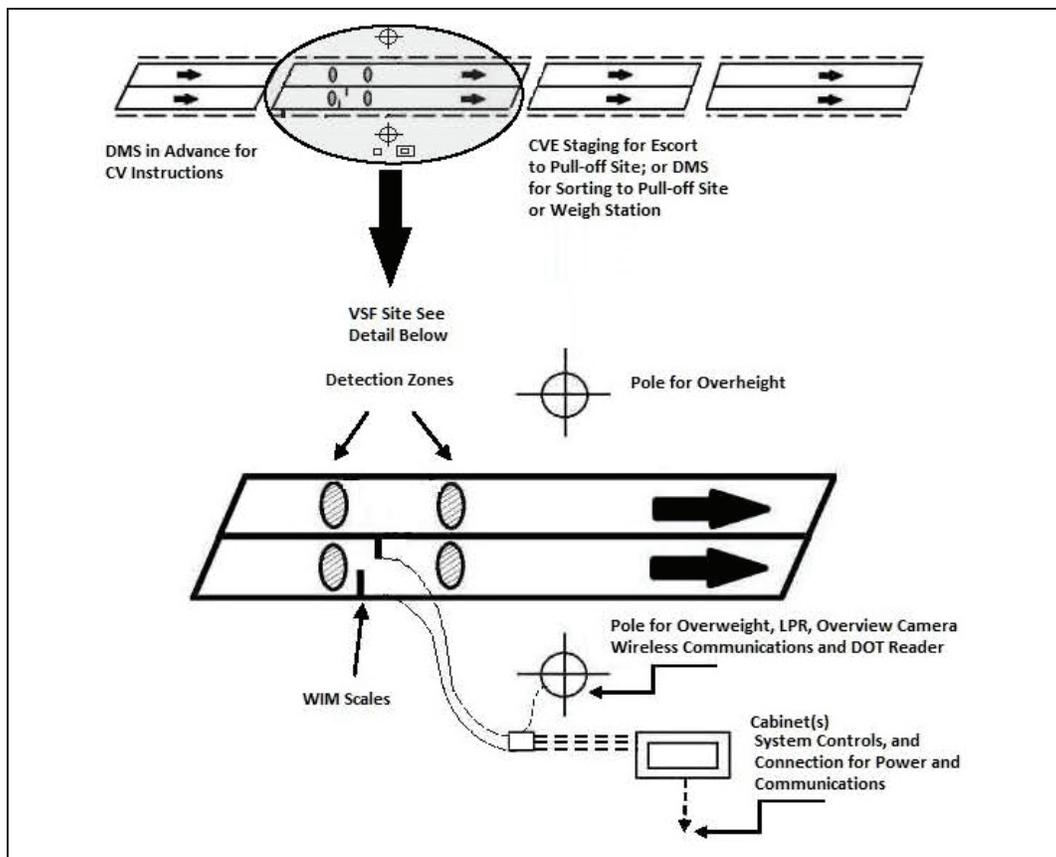


FIGURE 2.0. TYPICAL VSF OVERVIEW (SOURCE: ADAPTED FROM DELAWARE DEPARTMENT OF TRANSPORTATION, REQUEST FOR PROPOSALS, CONTRACT NO: 1723, VIRTUAL WEIGH STATIONS, 2014)

Appendix A: Virtual Weigh Station Deployment includes two figures from the report, Smart Roadside Initiative Gap Analysis: State of the Practice – Final.⁴ These figures show the operational flow of a typical virtual weigh station deployment and technologies used to support virtual weigh station deployments.

⁴ U.S. Department of Transportation, Intelligent Transportation Systems Joint Program Office by Cambridge Systematics, Inc., March 2014 (S. Capecci, M. Jensen, B. Rivenburg, R. Schiller)

2.1 STATEMENT OF PURPOSE: INNOVATIVE TECHNOLOGY DEPLOYMENT PROGRAM

As part of this project, CTDOT and CTDMV developed the following Statement of Purpose for Innovative Technology Deployment (ITD) Program initiatives for Connecticut's Commercial Vehicle Enforcement Program.

The Innovative Technology Deployment (ITD) Program (formerly known as CVISN) is a key component of the Federal Motor Carrier Safety Administration's (FMCSA's) drive to improve commercial motor vehicle safety. The ITD Program supports FMCSA's goals by focusing safety enforcement on high-risk operators; integrating systems to improve the accuracy, integrity, and verifiability of credentials; improving efficiency through electronic screening of commercial vehicles; and enabling online application and issuance of credentials.

As part of the ITD Program, the Connecticut Department of Transportation (CTDOT) and Connecticut Department of Motor Vehicles (CTDMV) will collectively deploy technologies and systems will help to protect the state's infrastructure and reduce the operation of unsafe commercial vehicles on the state's roadways. These improvements will clearly address the mission⁵ and vision⁶ of both CTDOT and CTDMV.

Initiatives, such as the installation of virtual e-screening sites along all interstates leading into and throughout Connecticut, will be utilized for the objective of monitoring commercial vehicles for volume, safety, weight, and registration compliance. Therefore, virtual e-screening sites will provide CTDOT and CTDMV with the necessary tools and information to enable effective enforcement, planning, policy actions and decisions to achieve a safe, predictable, and sustainable movement of goods throughout the state's highway network.

2.2 OVERVIEW: SCOPE OF WORK

A goal of this study is to identify and select virtual screening functionalities matched with enforcement strategies that provide flexibility, taking into consideration factors such as new technologies and changing enforcement strategies and traffic volumes over time. The focus needs to be the performance of the functions, using technology to support those functions. Desired outcomes include:

- positively changing the behavior of motor carriers/commercial vehicles and drivers that violate state and federal regulatory requirements;

5 The mission of CTDOT is to provide a safe and efficient intermodal transportation network that improves the quality of life and promotes economic vitality for the state and the region. The mission of CTDMV is to **promote public safety** and **regulate** drivers, their motor vehicles and certain vehicle-related businesses, through the **delivery of exceptional customer service** to internal and external customers.

6 The vision of CTDOT is to lead, inspire and motivate a progressive, responsive team, striving to exceed customer expectations. The vision of CTDMV is to continuously deliver **new and innovative ways** to provide **exceptional service to our customers** through **employees who are empowered** to make a difference.

- protecting the state's highway infrastructure;
- enabling motor carriers/commercial vehicles and drivers operating in a safe and legal manner to bypass inspection stations thus improving mobility by saving time, fuel and operational costs; and
- providing enhanced motor vehicle safety for the public.

CTDOT and CTDMV identified three priority roadway corridors as possible pilot virtual screening facility (VSF) sites for evaluation. These corridors were selected for consideration due to the lack of weigh station facilities in these areas to support commercial vehicles enforcement for commercial vehicles entering Connecticut near the state's borders.

- I-91 South near the Massachusetts State Line
- I-395 South near the Massachusetts State Line
- I-95 South near the Rhode Island State Line

This study includes the following:

- Identification of preferred roadway segments for selected priority corridor(s) as potential VSF site(s).
- Feasibility analysis of potential VSF sites. This analysis includes on-site visits to assess site geometry to determine the type of facility and technologies appropriate for use at each such site, evaluation of bypass potential, and a review of technical data such as current and forecasted commercial vehicle average daily traffic (ADT). Additionally, availability of high speed communication and electrical power was assessed.
- Review of the most appropriate functionalities and technologies.
- Identification of lessons learned from the experience of other states with the use of VSFs for commercial vehicle enforcement with a focus on the technologies and functionalities under consideration.
- List of technological components and data modules at the macro-level; micro-level information is typically proprietary.
- Estimated turn-key cost range for equipment and installation for the selected pilot VSF.
- Estimated cost range for system maintenance; actual cost will be based on the maintenance schedule of the selected vendors and the specific equipment installed.
- Implementation/time frame steps, including sequence and dependencies for the selected VSF pilot project site.
- Provide guidance for the prioritization of VSF site installations throughout the state, including consideration of the potential sites not selected for the pilot project and existing weigh stations.

2.3 OVERVIEW: CONNECTICUT'S COMMERCIAL VEHICLE ENFORCEMENT PROGRAM

Three state agencies are involved in the operation of Connecticut's Commercial Vehicle Enforcement Program: Connecticut Department of Motor Vehicles (CTDMV), Connecticut Department of Transportation (CTDOT), and the Connecticut Department of Emergency Services and Public Protection's Division of State Police (CSP).

CSP and CTDMV share the commercial vehicle enforcement responsibilities, operating weigh station facilities per §14-270c of the Connecticut General Statutes and conducting mobile enforcement activities.

CTDOT is responsible for the design, construction, and maintenance of the weigh station facilities. The Office of Construction is responsible for the construction of weigh stations, the Office of Maintenance for the maintenance of equipment and pavement, and the Office of Facilities handles contracts for maintenance and calibration of static scales and maintenance of buildings located at each weigh station. CTDOT is also responsible for the state's oversize and overweight commercial vehicle program including the issuance of oversize/overweight permits, development and submission of an annual commercial vehicle size and weight program plan to the Federal Highway Administration (FHWA) and the filing of an annual plan compliance report with FHWA.

Currently, there are six weigh station facilities located in the state as follows: Greenwich, I-95 Northbound; Waterford, I-95 Northbound, Waterford, I-95 Southbound, Danbury, I-84 Eastbound; Union, I-84 Westbound; and Middletown, I-91 Northbound. These weigh stations are all equipped with static scales, but none utilize technologies for mainline commercial vehicle screening for focusing enforcement activities on potential violators. A map depicting the existing weigh stations and the VSF sites under consideration is shown in Section 3, Figure 3.3.

An example of the results of the state's commercial vehicle enforcement program is the following summary of commercial vehicle weight enforcement using static and portable scales at weigh stations and through mobile enforcement for the federal fiscal years 2008 – 2016.

- Annual average of overweight citations issued was 1.9% for this period (3,633 overweight citations with a total of 193,953 vehicles weighed). Additionally, for this period there was a downward trendline in the percentage of overweight citations issued from 2.2% to 1.8%)
- CSP and CTDMV mobile (roving) enforcement portable scale weighing of commercial vehicles during this period ranged from a high of 3,713 (FFY10) to a low of 831 (FFY13) with a downward trendline in vehicles weighed from 3,500 to 780. An overview of mobile weight enforcement performance, calculated for FFY14, found that overweight citations issued were 57% of total vehicles weighed (479 overweight citations with a total of 841 vehicles weighed).

A summary of the results of this commercial vehicle weight enforcement analysis conducted for this study for the federal fiscal years FFY08 – FFY16 is shown in Figures 2.1 – 2.3.

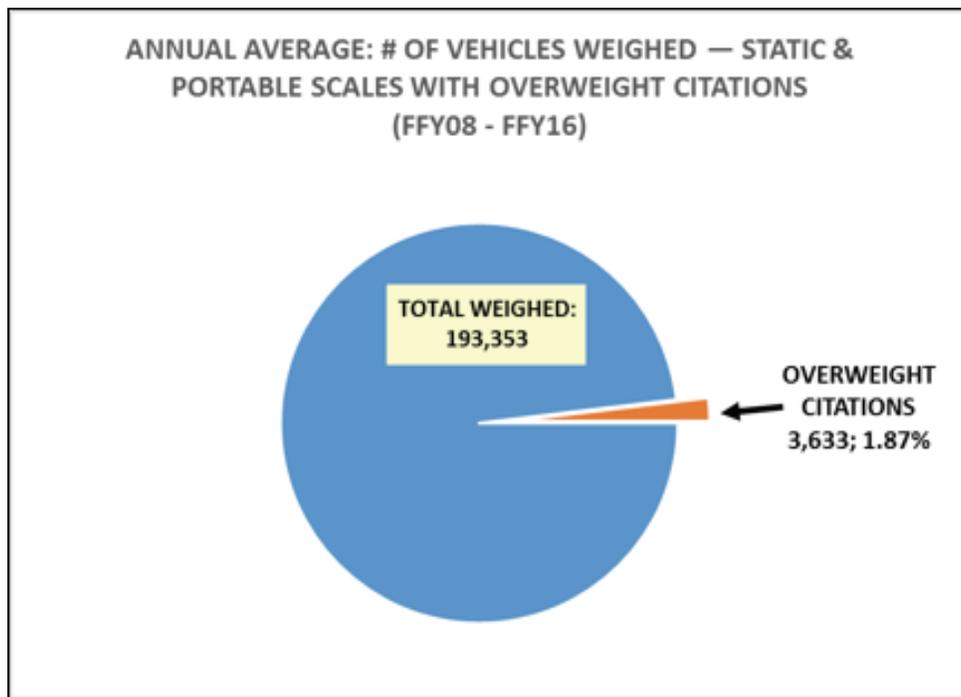


FIGURE 2.1. SUMMARY OF OVERWEIGHT CITATIONS (FFY08 - FFY16)

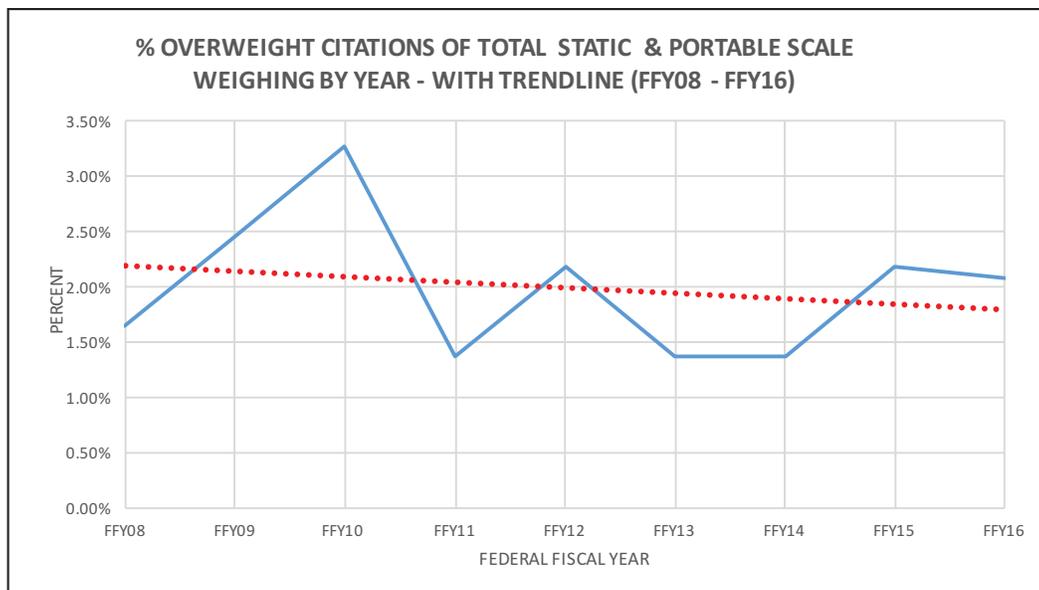


FIGURE 2.2. PERCENTAGE OF OVERWEIGHT CITATIONS BY YEAR (FFY08 - FFY16)

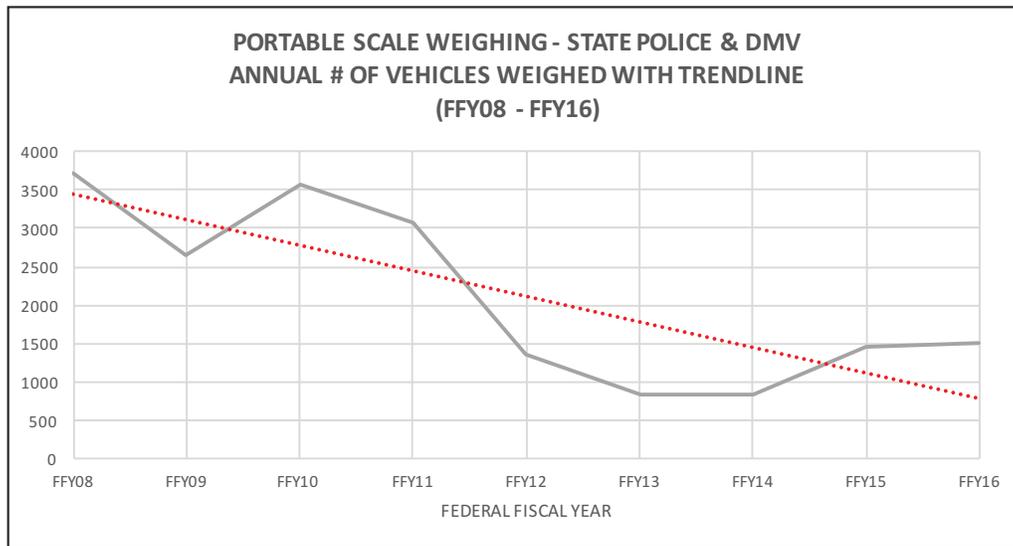


FIGURE 2.3. SUMMARY OF PORTABLE SCALE WEIGHING (FFY08 – FFY16)

Two recent studies conducted for CTDOT and CTDMV were reviewed for background purposes. These were

- Electronic Screening Modernization Study (2011) conducted on behalf of CTDMV by Cambridge Systematics⁷
- A Study of Weigh Station Technologies and Practices (2008) conducted on behalf of CTDOT by the Connecticut Academy of Science and Engineering⁸

2.4 COMMERCIAL VEHICLE ENFORCEMENT CHALLENGES

The CTDOT Statewide Freight Plan – Final Draft (2017) prepared by CDM Smith included information on truck movements and volumes for the base year of 2014 with forecasted movements and growth rates for 2040. Figure 2.4 depicts truck freight volume movements in 2014 and shows that I-95 (between Greenwich and New Haven), I-84 (between Danbury and the Massachusetts border) and I-91 (between New Haven and Hartford) have the highest level of truck tonnage movements in the state.

7 https://app.box.com/files/0/f/14569538188/1/f_112568430135

8 http://www.ctcase.org/reports/Weigh_stations.pdf

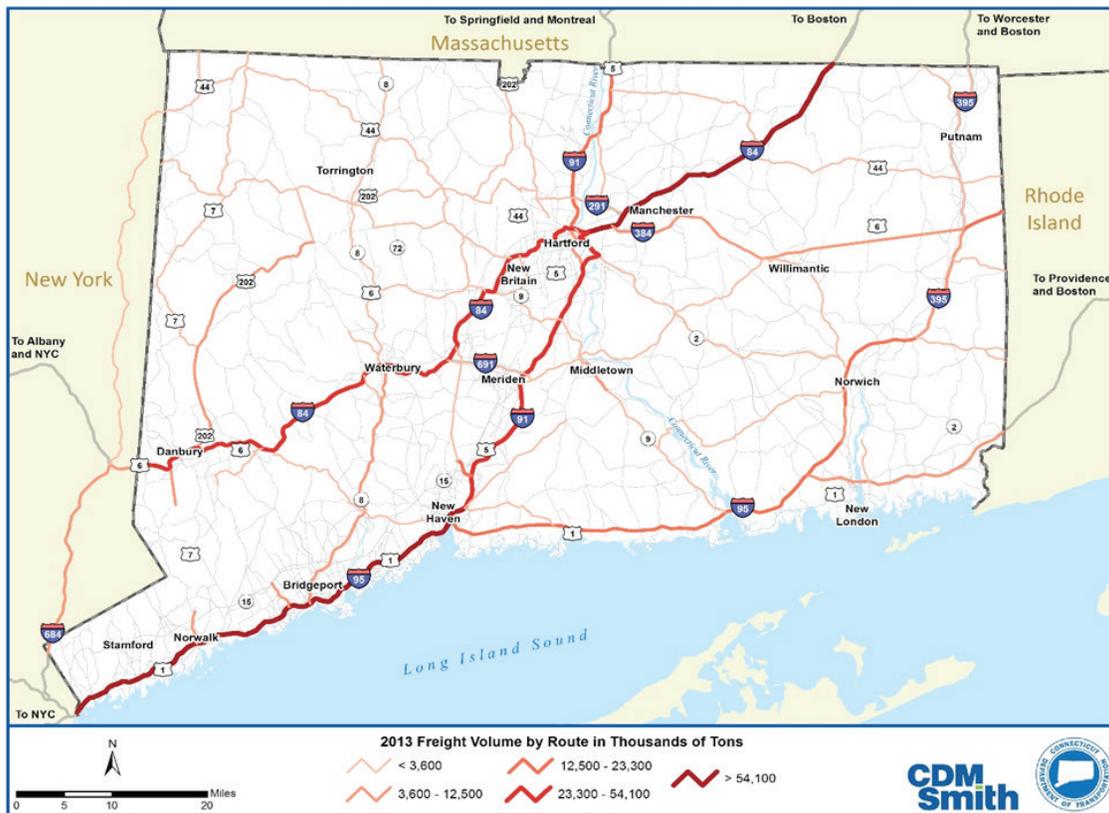


FIGURE 2.4. CONNECTICUT FREIGHT VOLUME MOVED BY TRUCK BY ROUTE, 2013 (SOURCE: CTDOT STATEWIDE FREIGHT PLAN – FINAL DRAFT, 2017; FIGURE 8-6: CONNECTICUT FREIGHT VOLUME MOVED BY TRUCK BY ROUTE, SOURCE: CDM SMITH AND IHS-TRANSEARCH DATA)

Figure 2.5 shows absolute truck tonnage growth on Connecticut roadways from 2014 to 2040. The greatest tonnage increase is on the routes that currently have the greatest freight density – I-95 from Greenwich to New Haven, I-91 New Haven to Hartford, and I-84 from Hartford to the Massachusetts border. Additionally, for the period of 2014 – 2040, the Freight Plan states “truck tonnage is forecast to increase from 198.7 million in 2014 to 315.4 million in 2040, an increase of 58.7% (1.8% annually).” Additionally, the Freight Plan indicates “truck freight-related vehicle miles traveled is expected to increase 88% from 2009 to 2040. Through freight is projected to account for the largest share of the forecasted increase in Connecticut’s freight truck travel, which is expected to increase by 103%.”⁹

9 Development of a Strategic Plan for Reducing Emissions Associated with Freight Movement, Connecticut Department of Energy and Environmental Protection, July, 2011; Cited in CTDOT Statewide Freight Plan – Final Draft, 2017

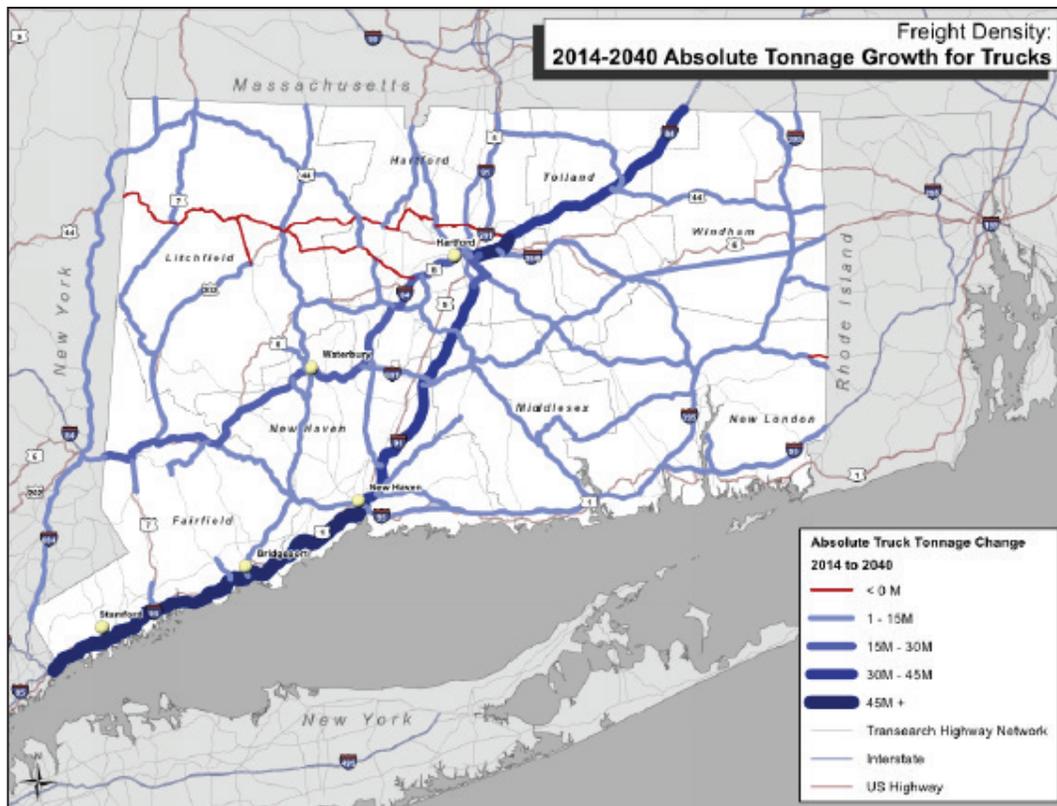


FIGURE 2.5. FREIGHT DENSITY: 2014 – 2040 ABSOLUTE TONNAGE GROWTH FOR TRUCKS (SOURCE: CTDOT STATEWIDE FREIGHT PLAN – FINAL DRAFT, 2017; FIGURE 8-13: CONNECTICUT TRUCK FREIGHT TONNAGE GROWTH, SOURCE: CDM SMITH AND IHS-TRANSEARCH DATA)

This will place increased importance on the strategic use of technologies and enforcement staff needed to maintain an effective commercial vehicle enforcement program. Conversely, an ineffective commercial vehicle enforcement program should be expected to result in an increased rate of damage to highway infrastructure and failure to identify commercial vehicles that are overweight, oversized, and/or with out-of-service violations.

2.5 STAKEHOLDER NEEDS, EXPECTATIONS AND PREFERRED PROCESSES

2.5.1 Programmatic Needs

Stakeholders impacted by or with interest in the development and operation of VSFs in Connecticut include CSP, CTDMDV, CTDOT, FHWA, FMCSA, trucking associations, motor carriers, technology integrators, technology manufacturers and vendors, highway and commercial vehicle safety organizations, and the public.

Current and forecasted growth in commercial vehicle movements – inbound, outbound, within, and through Connecticut – as shown in the 2017 CTDOT Statewide Freight Plan: Final Draft (Section 2.4, above) should be considered for maintaining an effective commercial vehicle

enforcement program. Based on this information, and CSP and CTDMV staffing, strategies to support commercial vehicle enforcement include:

- Expanding the commercial vehicle enforcement network to cover highways and roadways that are not protected by existing fixed weigh stations and enforcement operations.
- Utilizing technologies installed on the mainline to screen and process all commercial vehicles allowing those in compliance to bypass enforcement sites (VSFs and weigh stations) and only stop those commercial vehicles for inspection that may be a safety risk or exceed weight limits.
- Analyzing commercial vehicle enforcement system and CTDOT planning data and information.

2.5.1.1 PUBLIC AND PRIVATE STAKEHOLDERS COMMON NEEDS WITH RESPECT TO THE BENEFITS OF USING VSFS

- Improve commercial vehicle compliance with safety and weight regulations
- Decrease the numbers of fatalities and injuries on highway system
- Reduce the numbers of crashes involving commercial vehicles
- Preserve the highway pavement and bridge infrastructure
- Reduce delay on highways for all vehicle types
- Reduce fuel consumption for all vehicles

2.5.1.2 STATE AND FEDERAL PUBLIC AGENCY STAKEHOLDERS ADDITIONAL NEEDS FOR USE OF VSFS

- Increase the efficiency and effectiveness of roadside commercial vehicle and driver enforcement operations
- Improve motor carrier compliance with federal and state commercial vehicle size and weight regulations
- Lower infrastructure cost for enforcement of commercial vehicles
- Provide data for traffic monitoring, pavement monitoring, and operational planning

2.5.1.3 MOTOR CARRIER STAKEHOLDERS SPECIFIC NEEDS

- Provide recognition and a level playing field for safe and legal commercial motor carriers
- Improve the reliability of scheduling highway-based freight deliveries
- Improve the productivity and efficiency of trips

2.5.2 *Expectations*

2.5.2.1 EXPECTATIONS FOR THE DEPLOYMENT AND OPERATION OF VSFs

- Commercial vehicle traffic is projected to increase annually (2014 – 2040) based on the CTDOT 2016 freight study.
- Commercial vehicle enforcement staff will perform weight and safety inspections at newly developed VSF sites, as well as existing weigh stations.
- Proven technologies are available to identify commercial vehicles traveling at normal highway speeds
- Proven technologies are available to weigh commercial vehicles traveling at normal highway speeds
- Potential commercial vehicle violators by weight, safety, credentials, and other factors can be identified with data delivered to enforcement staff in real-time for selecting commercial vehicles to be inspected.
- Cost of deploying a VSF is considerably lower than construction of a new fixed weigh station.
- A VSF must have adequate pull-off area(s) for direct enforcement throughput to be effective.
- VSFs have the functionality to collect data 24/7. Analysis of system data can be used to make operational staff deployment-scheduling decisions to improve enforcement effectiveness. A fixed weigh station without VSF functionality when closed has no commercial vehicles processing through it, and no data available for use in making operational staff deployment-scheduling decisions.
- Commercial vehicles that have safety or weight issues may try to avoid VSFs and fixed weigh stations by traveling during times when weigh stations are closed, or on bypass routes or secondary roads. Possible enforcement strategies for bypass routes include maintaining a physical presence of enforcement personnel; use of cameras to monitor bypass routes with enforcement personnel dispatch to site pending level of activity; and establishing an enforcement site along the bypass route.
- VSFs have been shown to improve the effectiveness of commercial vehicle enforcement operations.
- VSF systems can also be used to enhance and support existing fixed weigh stations.

2.5.2.2 POTENTIAL CONSTRAINTS FOR VSF DEPLOYMENT

- On average LPR and USDOT# readers, types of automatic vehicle identification (AVI) systems, operate at about 80% accuracy. Comparatively, voluntary transponder and cellular based systems only have about 3%-10% of the commercial vehicle market.
- WIM systems can only be used for screening commercial vehicles for static/portable scale weighing. They are not legal for use for direct enforcement.

- E-Logbooks Vehicle to Roadside Infrastructure (V2I) is early in development and needs more testing to become a proven functionality for deployment as screening tool.

2.5.3 Preferred Processes for VSF Operations and Enforcement Staff

The operation of the pilot VSF and enforcement strategies utilized should be evaluated for lessons learned and success in achieving CTDOT and CTDMV objectives. Results from the pilot project will help determine the benefit of investing in additional VSF deployments to support CTDMV commercial vehicle enforcement and CTDOT planning and infrastructure protection. Some of these needs are in common between state agencies (CTDOT/CTDMV) and other needs are specific to each state agency's needs (CTDOT) or (CTDMV). VSFs and enforcement operations should have the functionality to perform the following:

- Allow safe and legal motor carriers/commercial vehicles to travel unimpeded by bypassing commercial vehicle enforcement sites(CTDOT/CTDMV)
- Identify motor carriers and commercial vehicles on the mainline at highway speeds (CTDMV)
- Use WIM screening functionality to separate commercial vehicles that are potential weight violators from the mainline traffic stream. Intercept potential commercial vehicle weight violators using sorting with signage or enforcement officer escort strategies to a pull-off location for weighing on scales used for enforcement (CTDMV)
- Use AVI and data clearinghouse data screening functionality to separate safety risk motor carriers and commercial vehicles from the mainline traffic stream. Intercept potential safety risk motor carriers/commercial vehicles, and drivers using sorting with signage or enforcement officer escort strategies to a pull-off location for safety inspection for enforceable actions (CTDMV)
- Collect continuous commercial vehicle and carrier data 24/7 for planning purposes and transparency and analysis making the data available electronically to authorized stakeholders, including the following among others. (CTDOT/CTDMV)
 - o Deployment of enforcement staff and other resources (CTDMV)
 - o Pavement and bridge monitoring (CTDOT)
 - o Analysis of travel and weight and safety trends (CTDOT/CTDMV)
- Confirm CTDOT issued permits and compliance (CTDOT/CTDMV)

3.0 FEASIBILITY ANALYSIS

3.1 SELECTION OF PRIORITY CORRIDORS

In preparation for this study, CTDOT and CTDMV selected three priority corridors for evaluation as potential VSF sites including: I-91 South near the Massachusetts State Line; I-395 South near the Massachusetts State Line; I-95 South near the Rhode Island State Line. The general criteria used for evaluation by CTDOT and CTDMV for selection of these three corridors included:

- No weigh stations located along the corridor in proximity to the potential VSF sites to support commercial vehicle enforcement
- Possibility of use of the corridor as a bypass from another corridor with a weigh station for entering Connecticut
- Relatively close proximity to Connecticut's state border so as to weigh and inspect commercial vehicles before traveling on Connecticut highways
- Volume of freight commodity flow in the corridor

TABLE 3.0. SUMMARY OF ANALYSIS OF PRIORITY CORRIDORS

Criteria	PRIORITY CORRIDOR		
	I-91 South	I-395 South	I-95 South
Proximity of the Priority Corridor to Connecticut State Border to Screen CVs Entering Connecticut	I-91 SB near the Massachusetts border	I-395 SB near the Massachusetts border	I-95 SB near the Rhode Island border
Current Type of CV Enforcement	Mobile Enforcement Only; No Fixed Weigh Stations	Mobile Enforcement Only; No Fixed Weigh Stations	Mobile Enforcement; Note: Waterford SB Weigh Station (25 Miles from RI Border)
Possible Use of Priority Corridor as Bypass from Another Corridor	Bypass to avoid I-84 WB Union Weigh Station	None	None
Commodity Flow Density, 2014* (tonnage – bi-directional; directional data not available) * CTDOT Statewide Freight Plan: Final Draft (2017)	<ul style="list-style-type: none"> • MA Border to I-84 (Hartford): 12M–24M • I-84 (Hartford) to I-691: 24M–48M • I-691 to I-95 (New Haven): 48M+ 	<ul style="list-style-type: none"> • MA Border to RT. 6: <6M • U.S. Route 6 to I-95 (East Lyme): 12M–24M 	<ul style="list-style-type: none"> • RI Border to I-395 (East Lyme): 6M–12M • I-395 (East Lyme) to I-91 (New Haven): 12M–24M • I-95 (New Haven to NY Border): 48M+

3.2 PREFERRED ROADWAY SEGMENT ANALYSIS

The feasibility analysis for selection of a pilot VSF site or sites was conducted by the CASE Research Team utilizing available data, site visits, discussions with CTDOT and CTDMV regarding operations and strategies, and anecdotal information provided by the departments. The CASE Research Team, CTDOT, and CTDMV toured each of the priority corridors and potential preferred roadway segments for each corridor in February, 2017. The site visits were used to verify and confirm potential locations for VSF sites including site geometry and potential availability of electrical power and communications in proximity of the sites, and proximity of direct enforcement sites (safe pull-off locations for weigh and safety inspection of commercial vehicles and drivers). Additionally, the tour included visits to each of the state's six fixed weigh stations to observe operations and facility characteristics. The feasibility analysis was used to develop a consensus by CTDOT and CTDMV for selection of a pilot VSF site(s).

The focus of the feasibility analysis was to examine the three priority corridors to identify a preferred roadway segment(s) for each corridor.

The initial step in this analysis was to assess each preferred roadway segment for suitability as a VSF and as a pilot project. Several factors were considered, including:

- Average daily traffic (ADT), provided by CTDOT, including vehicle classification and potential volume of commercial vehicles during peak hour
- Pull-off area in close proximity to the highway with adequate space and appropriate pavement specifications for conducting direct commercial vehicle enforcement

An evaluation of potential bypass routes around the VSF location was also included in the analysis. Commercial vehicles bypass VSFs and fixed weigh stations as a byproduct of risk versus reward. Risks include known safety, weight and size violations for which a commercial vehicle driver may receive a citation. As the cost of a potential citation increases, so does the risk of being convicted of a violation and the reward for evading inspection. Thus, in an effort to reduce overall costs some commercial vehicle drivers/companies may choose to accept the risk and operate with known safety, weight, or size violations.

Each of the VSF sites evaluated in this study, as well as the existing fixed weigh stations, has potential bypass routes that commercial vehicles can use to evade enforcement inspection. An enforcement strategy that can be used to discourage bypassing is for mobile enforcement staff to monitor identified bypass routes at key locations in the vicinity of highway exits or other strategic locations. Use of VSF type technologies or other types of monitoring cameras can also be used to assist enforcement staff to identify commercial vehicles travelling on these routes. The analysis describes the potential bypass routes for each VSF site that was evaluated. The information provided includes exit used to access the bypass route, the bypass route, and the exit number and route from the bypass route to return to I-91 Southbound that is located beyond the VSF and its related primary direct enforcement area site.

Based on the feasibility of the preferred roadway segment(s), further analysis was conducted, including:

INNOVATIVE TECHNOLOGY DEPLOYMENT: DEVELOPMENT OF A VIRTUAL SCREENING FACILITY PILOT PROJECT FOR CT'S COMMERCIAL VEHICLE ENFORCEMENT PROGRAM FEASIBILITY ANALYSIS

- Availability of electrical power and communication systems (fiber optics) to support data transfer and accessibility
- Geometry of the preferred roadway segment
- Environmental conditions
- Plans for future projects on the roadway segment

3.2.1 Identification of the Preferred Roadway Segment(s) for Each Priority Corridor

3.2.1.1 I-91 SOUTH NEAR THE MASSACHUSETTS STATE LINE

Potential sites in the vicinity of the Massachusetts state line were reviewed for suitability, with I-91 South at Route 510 selected as the preferred roadway segment. Preliminary review identified this site as appropriate for further analysis.

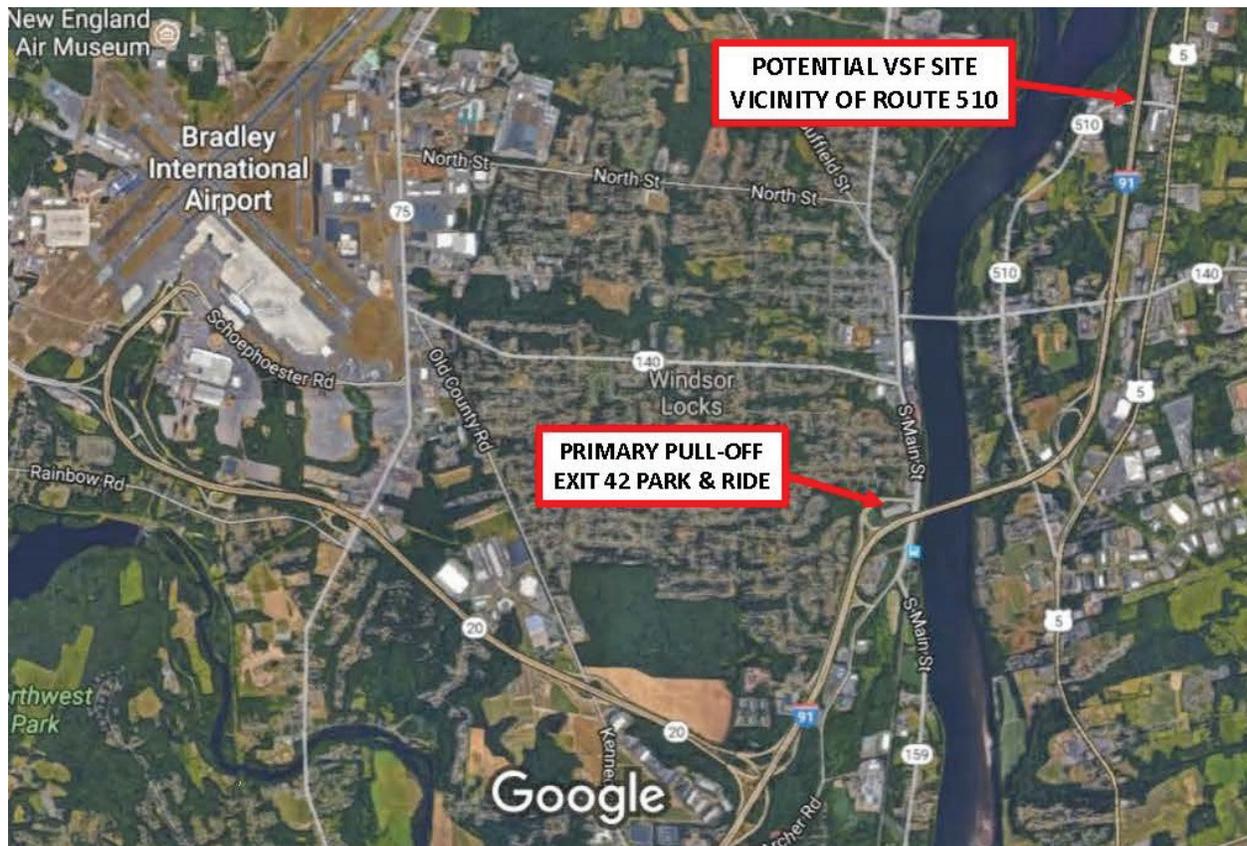


FIGURE 3.0. POTENTIAL VIRTUAL SCREENING FACILITY SITE: I-91 SOUTHBOUND IN THE VICINITY OF ROUTE 510 (SOURCE: GOOGLE MAPS (2017))

3.2.1.2 I-395 SOUTH NEAR THE MASSACHUSETTS STATE LINE

Initial review of potential preferred roadway segments in the proximity of I-395 South near the state border revealed a lack of acceptable direct enforcement sites. As a result, it was found that the closest potential site for further analysis was located approximately 20 miles from the border, south of U.S. Route 6 in the vicinity of the Plainfield Southbound Service Plaza. Additional locations identified for analysis along I-395 South included the Montville Southbound Service Plaza south of Route 2, and a site south of Route 85. Ultimately, the preferred roadway segment just south of U.S. Route 6 was chosen for this corridor because it was the closest site to the state border with an acceptable direct enforcement area.

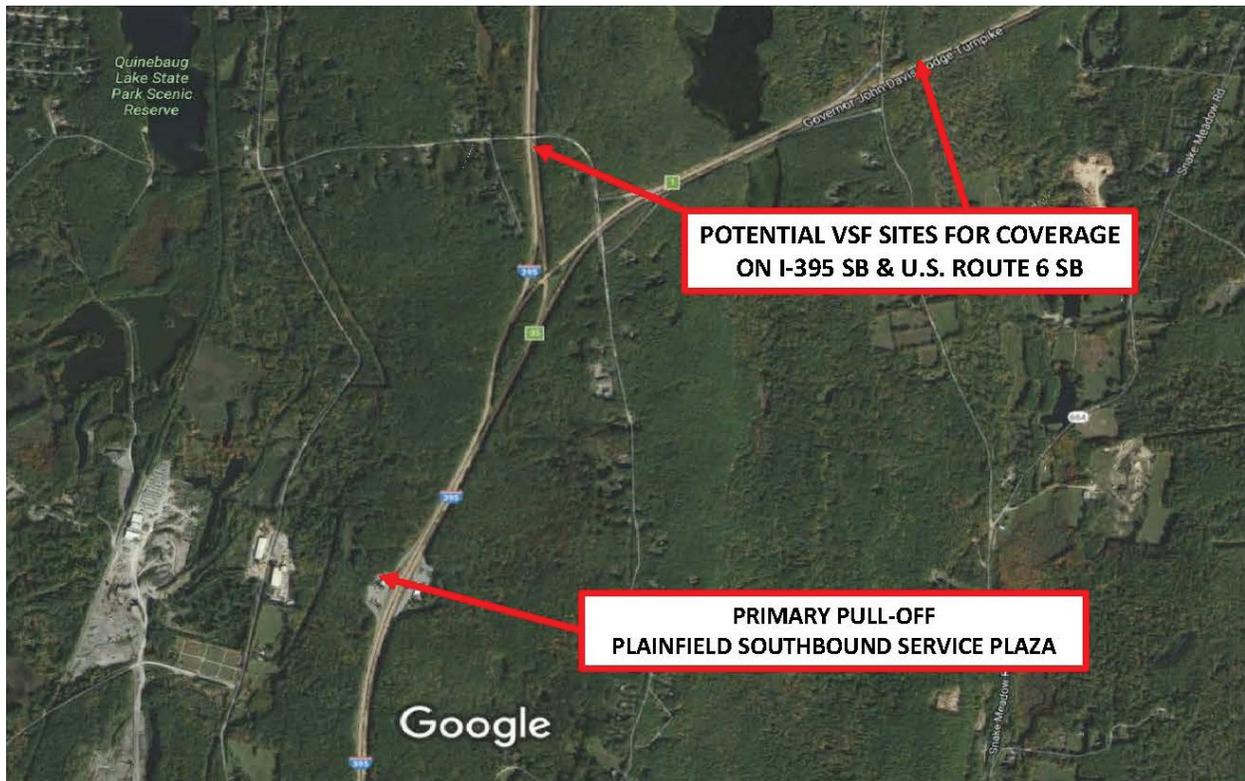


FIGURE 3.1. POTENTIAL VIRTUAL SCREENING FACILITY SITE: I-35 SOUTHBOUND IN THE VICINITY OF THE PLAINFIELD SOUTHBOUND SERVICE PLAZA SOUTH OF U.S. ROUTE 6 (SOURCE: GOOGLE MAPS (2017))

3.2.1.3 I-95 SOUTH NEAR THE RHODE ISLAND STATE LINE

Initial review of potential preferred roadway segments in the proximity of I-95 South near the Rhode Island state line found that the closest potential site for further analysis was located approximately three miles from the border at the Mystic/North Stonington Rest Area.

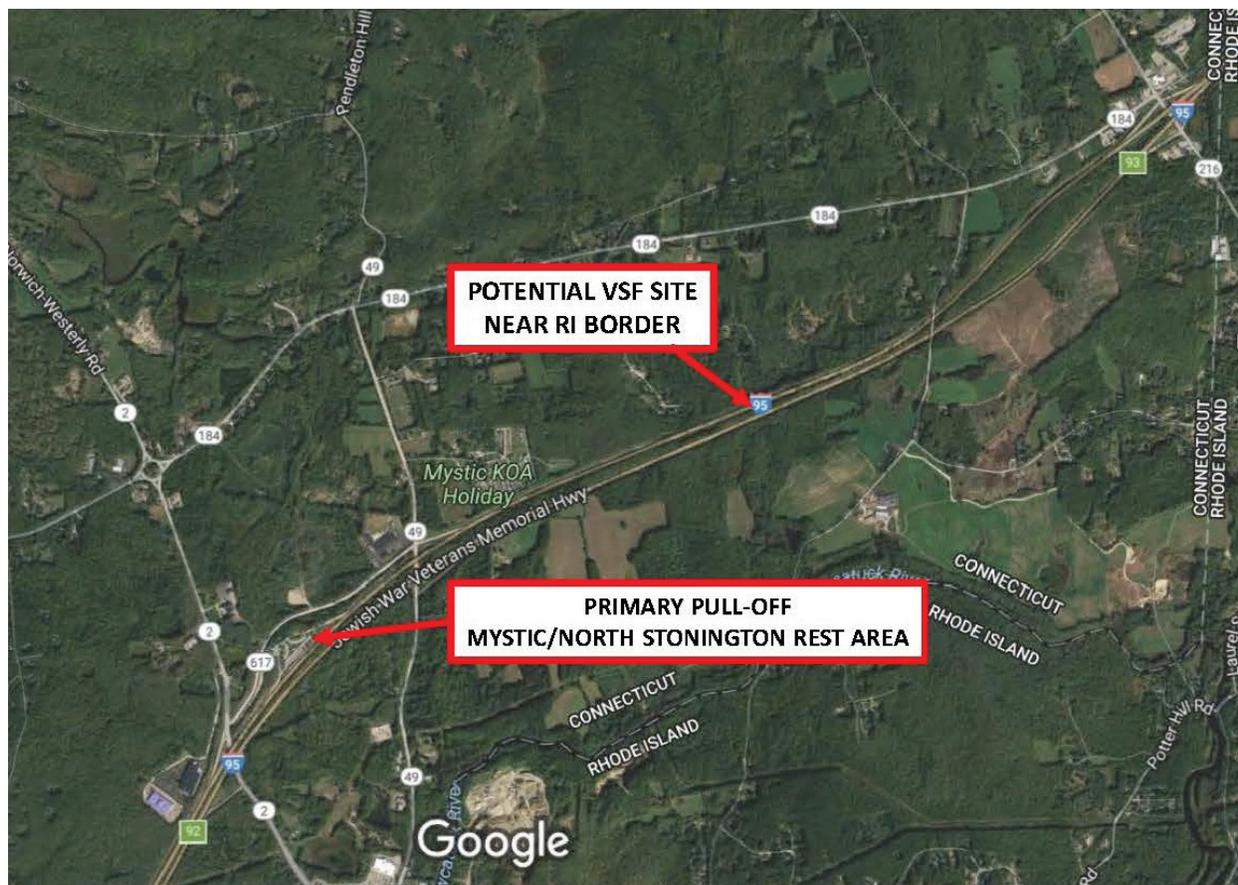


FIGURE 3.2. POTENTIAL VIRTUAL SCREENING FACILITY SITE: I-95 SOUTHBOUND IN THE VICINITY OF THE RHODE ISLAND BORDER (SOURCE: GOOGLE MAPS (2017))

3.2.2 Overview of the Preferred Roadway Segment Feasibility Analysis

Table 3.1 provides an overview of the analysis of the preferred roadway segments for each of the selected priority corridors.

INNOVATIVE TECHNOLOGY DEPLOYMENT: DEVELOPMENT OF A VIRTUAL SCREENING FACILITY PILOT PROJECT FOR CT'S COMMERCIAL VEHICLE ENFORCEMENT PROGRAM
FEASIBILITY ANALYSIS

TABLE 3.1. SUMMARY OF VIRTUAL SCREENING FACILITY SITING ANALYSIS – PREFERRED ROADWAY SEGMENTS

Criteria	PREFERRED ROADWAY SEGMENTS		
	I-91 SB @ Route 510	I-395 SB @ Plainfield Service Plaza South of U.S. Route 6	I-95 SB @ Mystic/North Stonington Rest Area
CV ADT Data Sampling (dates) Forecasted ADTs based on the 2017 CT DOT Statewide Travel Model Estimate for Growth from 2015 - 2040	1/17/17 – 1/18/17 I-91 SB @ Route 510 (Depot Hill Road); Average: Total 48,118; CV Single Unit and Articulated Trucks: 4,654 (9.7%); CV ADT forecast by 2040: +17%	5/17/17 – 5/18/17 I-395 SB North of Plainfield Service Area @ U.S. Route 6 Merge Average: Total 15,728; CV Single Unit and Articulated Trucks: 1,982 (12.5%); CV ADT forecast by 2040: +19%	6/8/17 – 6/9/17 I-95 SB between Exits 82 and 82A Average: Total 42,145; CV Single Unit and Articulated Trucks: 3,349 (8%); CV ADT forecast by 2040: +16%
VSF Design Hourly Volume	439 CVs/Hour	184 CVs/Hour	285 CVs/Hour
Proximity of Preferred Roadway Segment to Connecticut State Border	~6 Miles; VSF site to be located upstream of and in close proximity to the Route 510 overpass	~20 Miles; VSF site location to be upstream of Plainfield Service Plaza South of U.S. Route 6	~2 Mile; VSF site location to be upstream of the Mystic /North Stonington Rest Area
Planned Enforcement Strategy for Pilot Operations	Escort	Escort	Escort
Location Areas for Direct CV Enforcement	Primary: Exit 42- South Main Street (Route 159) @ Commuter Lot ~3 miles from VSF site @ Route 510 (342 car spaces; average occupancy 44%) Secondary: Sites at Exit 45 - Route 140; Exit 44 - U.S. Route 5; Exit 41-South Center Street; Exit 39 - Kennedy Road (88 spaces); Exit 38 - Route 75 (219 spaces)	Primary: Plainfield Service Plaza South of U.S. Route 6 ~1 mile from VSF site @ U.S. Route 6 interchange (10 truck spaces) Secondary: Montville Service Plaza~27 miles from VSF site @ U.S. Route 6 interchange (10 truck spaces)	Primary: Mystic/North Stonington Rest Area ~1 mile from VSF site @ Route 2/49 interchange (25 truck spaces) Secondary: Waterford SB Weigh Station ~19 miles from VSF site @ Cross Road exit, west of Route 85 interchange (5 truck spaces)
Potential Bypass Routes Around VSF Site	Exit 49 – U.S. Route 5; Exit 48 - Route 220; Exit 47 (E) & (W) - Route 190; Exit 46 - U.S. Route 5	Exit 41 to Route 12; Exit 37B - U.S. Route 6	Exit 93 - Route 184; Exit 1 (R1) to Route 3 to Route 78 to Route 2
VSF Site Geometry	Acceptable	Acceptable	Acceptable
Power Communications	Available from Route 510 Fiber Service Available from Route 510	Available from Squaw Rock Road and Ross Road Fiber Service Available from Ross Road	Available from Cranberry Bog Road Fiber Service Available from Route 216
Current Pavement Section	Flexible Asphalt; Concrete slab base material for outside two lanes	Flexible Asphalt; Broken stone base	Flexible Asphalt; Pre-mix asphalt base
Highway Maintenance	2015: Resurfacing - Mill 3" and Fill 3"; Next Resurfacing: ~ 2023-2025	1993: Milling and Resurfacing	2003: Resurfacing – Mill 3" and Fill 3" 2015: 0.5" – 1.0" Thin HMA, mainline lanes only I-95 expansion project to add lanes in early planning stage
Major Highway Projects	None	None	None
CV Enforcement Data: Mobile Enforcement Sampling Exercise	Dates: June 13-15, 2017 Inspection Summary Total # of inspections: 89; Level 1: 13 (14.6%); Level 2: 47 (52.8%); Level 3: 29 (32.6%) Out-of-Service Violations Summary Vehicles OOS: 26 (43.3%); Drivers OOS: 11 (12.4%); Total all violations: 268 (3.0 violations/inspection) Note: Based on inspector evaluation, no vehicles were weighed during sampling exercise Note: Vehicle OOS based on Level 1 & 2 inspections (60)	Dates: July 18-20, 2017 Inspection Summary Total # of inspections: 48; Level 1: 11 (22.9%); Level 2: 23 (47.9%); Level 3: 14 (29.2%) Out-of-Service Violations Summary Vehicles OOS: 17 (50%); Drivers OOS: 11 (12.36%); Total all violations: 290 (6.0 violations/inspection) Note: Vehicle OOS based on Level 1 & 2 inspections (34)	Mobile enforcement sampling exercise for this location not conducted

3.2.2.1 I-91 SOUTH AT ROUTE 510

This preferred roadway segment along the I-91 Southbound priority corridor at the Route 510 (Old Depot Road) overpass was selected for analysis. The VSF site will be located upstream of and in close proximity to the Route 510 overpass. The site meets the criteria in that it is close to the state border (approximately six miles); it is not protected with a fixed weigh station, and anecdotally, it serves as a bypass route for commercial vehicles that avoid the I-84 Westbound Union Weigh Station. Commodity flow in this section of the I-91 corridor is in the range of 12 – 24 million tons per year.¹⁰ In addition to commodity flow moving through the state on this corridor, inbound freight is also delivered to Bradley International Airport for shipping. ADT sampling on January 17 – 18, 2017, showed an average ADT of 4,654 commercial vehicles, representing 9.7% of total ADT of 48,118. The 2017 CTDOT Statewide Travel Model forecasts 17% ADT growth from 2015 - 2040. Based on this information, a design hourly volume of 439 commercial vehicles was estimated. The following provides additional information regarding the suitability of this site for use as a VSF pilot project:

- This roadway segment is a three-lane highway in good condition but does not meet the smoothness necessary for WIM control pavement
- Commercial vehicle traffic is 24 hours per day and 7 days per week
- The geometry of the VSF site is generally straight with good sightlines and longitudinal and cross slopes of less than 3%. These site characteristics meet the criteria for VSF WIM system accuracy, repeatability and reliability.
- No major projects or lane additions are planned for this roadway segment within the next ten years. The next resurfacing is anticipated for 2023 – 2025.
- Electrical power and fiber for communications are available in close proximity to the site.

Evaluation of Bypass Potential

This segment of I-91 has two parallel secondary roadway corridors – US Route 5 and Route 159 – that can be used as bypass routes. Table 3.2 shows the bypass options for the VSF located on I-91 Southbound at Route 510.

¹⁰ CTDOT Statewide Freight Plan – Final Draft, 2017; Figure 8-6: Connecticut Freight Volume Moved by Truck by Route, Source: CDM Smith and IHS-Transearch data

TABLE 3.2. BYPASS OPTIONS: I-91 SB AT ROUTE 510 VSF

I-91 SB Bypass Exit	Bypass Route	Bypass Return Route to I-91 SB
Exit 2 (Massachusetts)	US-5 SB	Exit 45 (Route 140) or Exit 44 (Newberry Road/US-5 Interchange)
Exit 49	US-5 SB	Exit 45 (Route 140) or Exit 44 (Newberry Road/US-5 Interchange)
Exit 48	Exit onto Route 220 WB to US-5 SB	Exit 45 (Route 140) or Exit 44 (Newberry Road/US-5 Interchange)
Exit 47W	Exit onto Route 190 WB to US-5 SB	Exit 45 (Route 140) or Exit 44 (Newberry Road/US-5 Interchange)
Exit 47W	Exit onto Route 190 WB to Route 159 SB	Exit 45 (Route 140) (Also see note)
Exit 46	US-5 SB	Exit 45 (Route 140) or Exit 44 (Newberry Road/US-5 Interchange)
Note: Possible diversion option: Route 159 SB to Route 75 SB to Route 20 onto I-91 SB, or continue on Route 159 to I-91 SB entrance ramp at primary VSF direct enforcement site (Commuter Lot) at Exit 42		

Figure 3.3 provides an overview of the I-91 exits that may be used to access bypass routes, the location of the VSF site and direct enforcement site, and the return route entrance exit numbers for re-entering I-91 beyond the VSF site.

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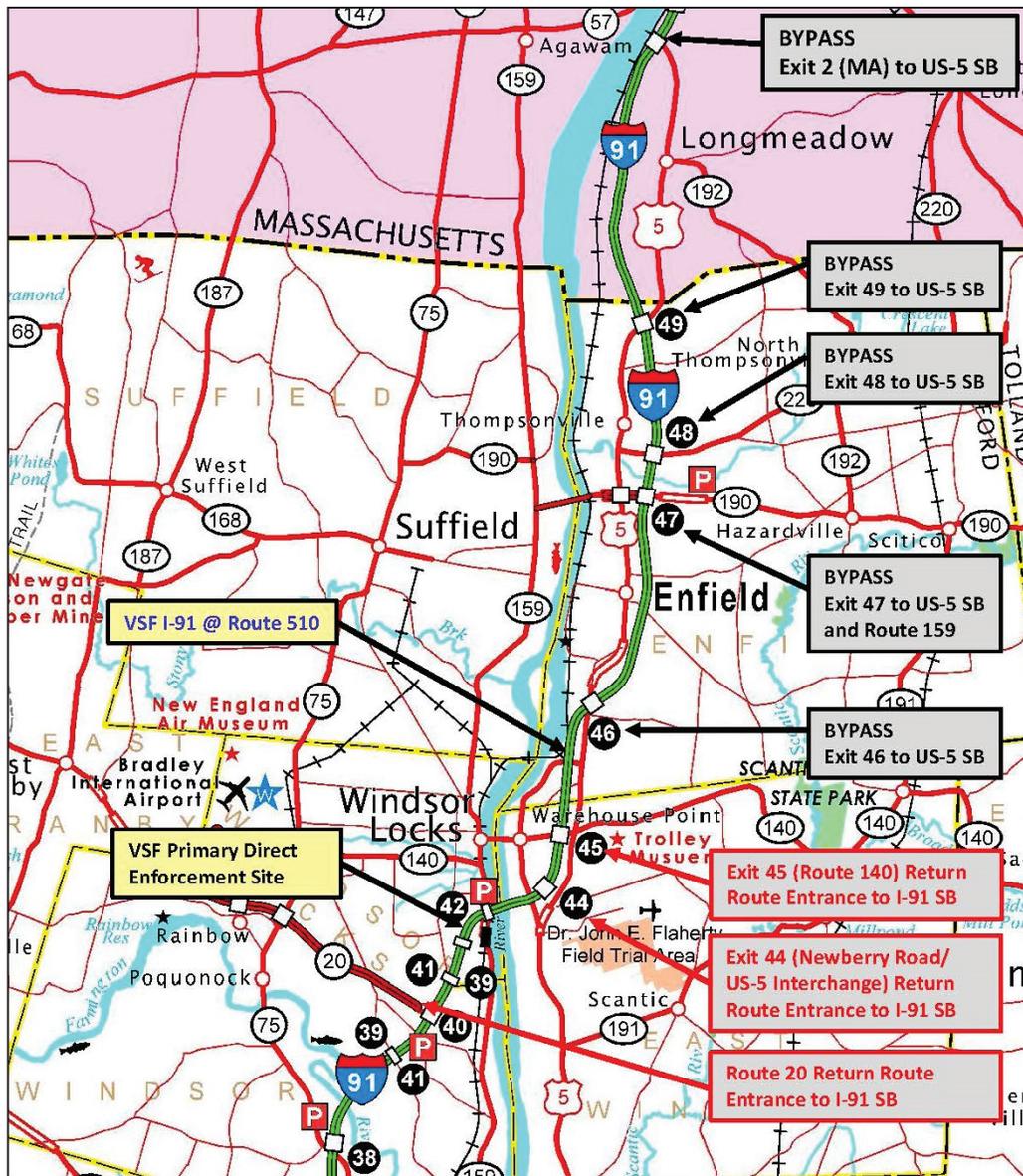


FIGURE 3.3. OVERVIEW OF BYPASS OPTIONS: I-91 SB AT ROUTE 510 VSF

Options for mobile enforcement bypass monitoring of southbound traffic include locating enforcement personnel at the following key locations, among others:

- US-5 and Route 510 intersection (primary location, less than three miles to the direct enforcement site at the Exit 42 Commuter Lot)
- Route 159 and Route 140 intersection (secondary location, less than one mile to the direct enforcement site at the Exit 42 Commuter Lot).

3.2.2.2 I-395 SOUTH AT THE PLAINFIELD SERVICE PLAZA SOUTH OF U.S. ROUTE 6

This roadway segment along the I-395 Southbound corridor at the U.S. Route 6 interchange was evaluated for consideration as preferred roadway for a pilot project. However, it was not selected as the preferred corridor for the pilot project, primarily due to lower truck volumes. This future VSF site on I-395 could be located about 1 mile upstream of the Plainfield Service Plaza. The site meets the criteria of being close to the state line (approximately 20 miles) and not protected with a fixed weigh station. Commodity flow in this section of the I-395 corridor is in the range of 1 – 15 million tons per year.¹¹ ADT sampling on May 17 – 18, 2017 showed an average ADT of 1,962 commercial vehicles, representing 12.5% of total ADT of 15,728. The 2017 CTDOT Statewide Travel Model forecasts 19% ADT growth from 2015 – 2040. Based on this information, a design hourly volume of 184 commercial vehicles was estimated. The following provides additional information regarding the suitability of this site for use as a future VSF project:

- This roadway segment is a two-lane highway in good condition, but does not meet the smoothness required for WIM control pavement
- Commercial vehicle traffic is 24 hours per day and 7 days per week
- The geometry of the VSF site is generally straight, with good sightlines and longitudinal and cross slopes of less than 3%. These site characteristics meet the criteria for VSF WIM system accuracy, repeatability and reliability.
- No major projects or lane additions are planned for this roadway segment within the next ten years. The next resurfacing is currently not scheduled.
- Electrical power and fiber for communications are available in close proximity to the site.

Evaluation of Bypass Potential

This segment of I-395 has two parallel secondary roadway corridors, Route 12 and Route 169, that can be used as bypass routes. Table 3.3 shows the bypass options for a VSF that would be located on I-395 in the vicinity of the Plainfield Service Plaza just south of the U.S. Route 6 entrance connector to I-395.

TABLE 3.3. BYPASS OPTIONS: I-395 SB AT THE PLAINFIELD SERVICE PLAZA VSF

I-395 SB Bypass Exit	Bypass Route	Bypass Return Route to I-395 SB
Exit 41	Exit onto Route 101 to Route 12 SB or Route 169	Exit 32 (Route 14)
Exit 37B	Exit onto US-6 WB to Route 12 SB or Route 169	Exit 32 (Route 14)
<p>Notes</p> <p>Commercial vehicles travelling on US-6 WB heading to I-395 SB may bypass the I-395 SB entrance ramp by continuing on US-6 to Route 12 SB</p> <p>Commercial vehicles diverting to Route 169 may use any of several entrance ramps to return to I-395 SB in addition to Exit 32 (Route 14), including Exit 29 (Route 14A), and Exit 19 (Route 169)</p>		

¹¹ Ibid.

Figure 3.4 provides an overview of the I-395 exits that may be used to access bypass routes, the location of the VSF site and direct enforcement site, and the return route entrance exit numbers for re-entering I-395 beyond the VSF site.

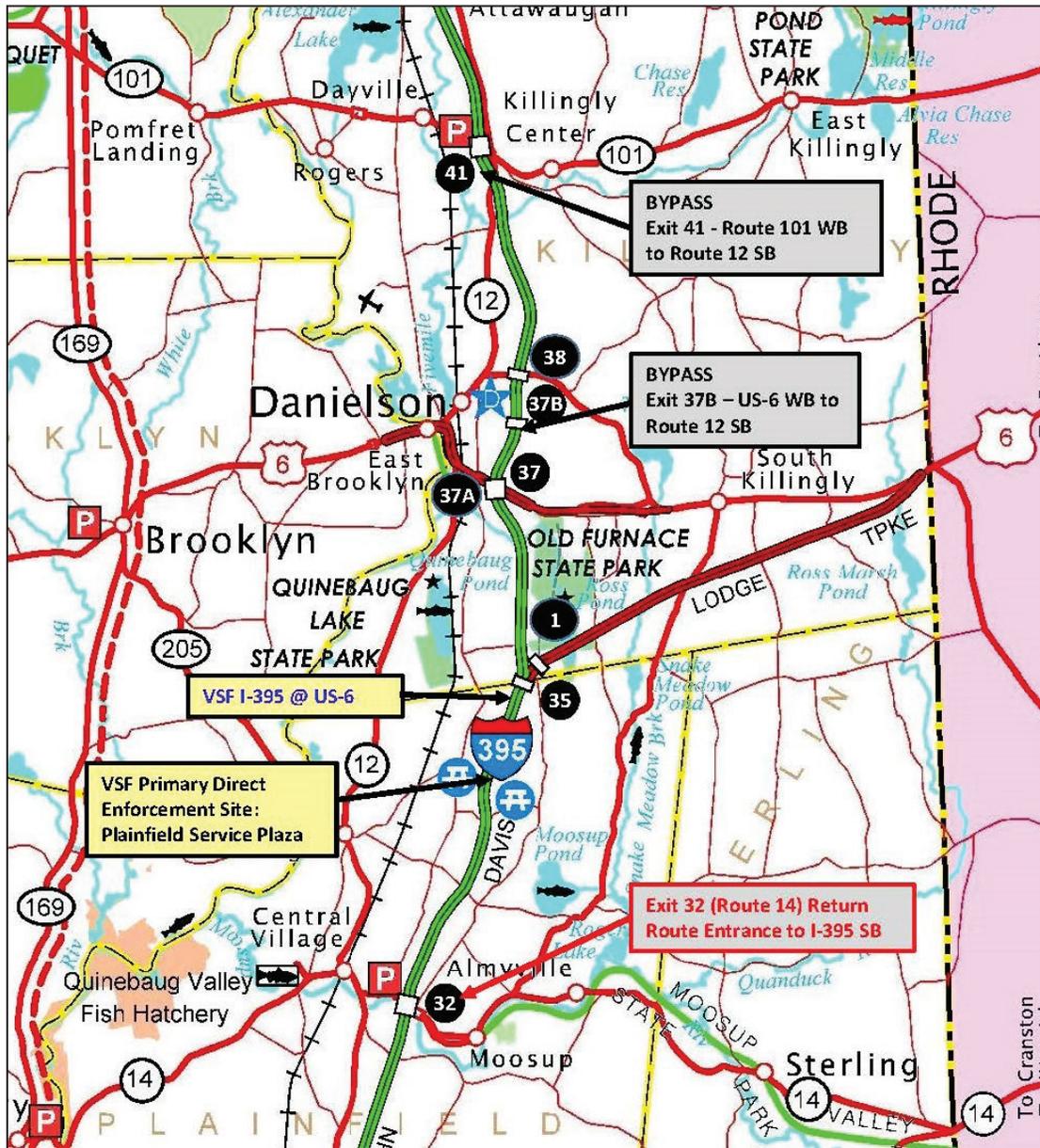


FIGURE 3.4. OVERVIEW OF BYPASS OPTIONS: I-395 SB AT THE PLAINFIELD SERVICE PLAZA VSF

Options for mobile enforcement bypass monitoring of southbound commercial vehicles include locating enforcement personnel at the following key location, among others:

- US-6 and Route 12 intersection west of I-395 (Exit 37) (primary location, less than four miles to the direct enforcement site at the Plainfield Service Plaza).

- US-6 at the Rhode Island border for commercial vehicles entering the state and remaining on US 6, bypassing the entrance to I-395 SB.

3.2.2.3 I-95 SOUTH AT THE MYSTIC/NORTH STONINGTON REST AREA

This roadway segment along the I-95 Southbound corridor at the Route 2/ Route 49 interchange was evaluated for consideration as preferred roadway for a pilot project. However, it was not selected as the preferred corridor for the pilot project, primarily due to lower truck volumes on this corridor. This future VSF site on I-95 could be located about one mile upstream of the Mystic / North Stonington Rest Area. The site meets the criteria of being close to the state line (approximately two miles) and currently protected with commercial vehicle enforcement part time at the Waterford Southbound fixed weigh station. Commodity flow in this section of the I-95 corridor is in the range of 1 – 15 million tons per year.¹² ADT sampling on June 8 – 9, 2017 showed an average ADT of 3,350 commercial vehicles, representing 8% of total ADT of 42,145. The 2017 CTDOT Statewide Travel Model forecasts 16% ADT growth from 2015 – 2040. Based on this information a design hourly volume of 285 commercial vehicles was estimated. The following provides additional information regarding the suitability of this site for use as a future VSF project:

- This roadway segment is a two-lane highway in fair condition but does not meet the smoothness required for WIM control pavement
- Commercial vehicle traffic is 24 hours per day and 7 days per week
- The geometry of the VSF site is generally straight with good sightlines and longitudinal and cross slopes of equal to or less than 3%. These site characteristics meet the criteria for VSF WIM system accuracy, repeatability and reliability.
- No major projects or lane additions are planned for this roadway segment within the next ten years. The next resurfacing is not currently scheduled.
- Electrical power and fiber for communications are available in close proximity to the site.

Evaluation of Bypass Potential

This segment of I-95 has two parallel roadway corridors, Route 184 and the routing of Route 3 (RI) to Route 78 (RI) to Route 2, that can be used as bypass routes. Table 3.4 shows the bypass options for a VSF that would be located on I-95 in the vicinity of the Mystic/North Stonington Rest Area south of Exit 93.

TABLE 3.4. BYPASS OPTIONS: I-95 SB AT THE MYSTIC/NORTH STONINGTON REST AREA VSF

I-95 SB Bypass Exit	Bypass Route	Bypass Return Route to I-95 SB
Exit 1 (Rhode Island)	Route 3 (RI) SB to Route 78 WB (RI) to Route 2 NB	Exit 92 (Route 2)
Exit 93	Route 184 WB	Exit 92 (Route 2)

Figure 3.5 provides an overview of the I-95 exits that may be used to access bypass routes, the

12 Ibid.

location of the VSF site and direct enforcement site, and the return route entrance exit numbers for re-entering I-95 beyond the VSF site.

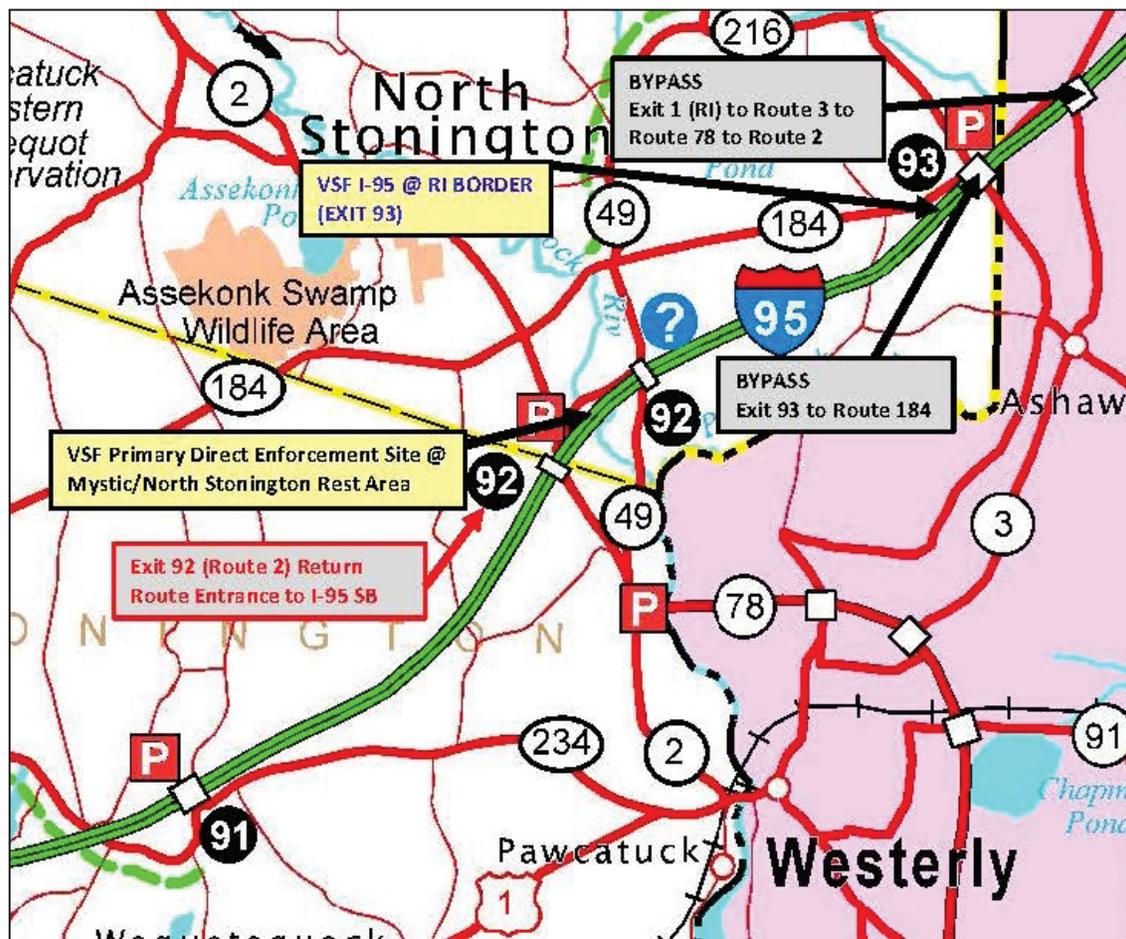


FIGURE 3.5. OVERVIEW OF BYPASS OPTIONS: I-95 SB AT THE NORTH STONINGTON REST AREA VSF

Options for mobile enforcement bypass monitoring of southbound commercial vehicles include locating enforcement personnel at the following key location, among others:

- Exit 93 and Route 216 intersection and Route 184 (primary location, about three miles to the direct enforcement site at the Mystic/North Stonington Rest Area).
- Route 2 and Route 617 intersection (primary location, about 1/4 mile to the direct enforcement site at the Mystic/North Stonington Rest Area).
- Route 78 and Route 2 intersection (Commuter Lot at Liberty Street, Pawcatuck)

3.2.3 Preferred Roadway Segment Pilot VSF Site Selection

Review of the feasibility analysis with CTDOT and CTDMV staff resulted in the selection of the I-91 South priority corridor upstream and in close proximity to the Route 510 overpass as the preferred roadway segment for development and deployment of the first pilot VSF site. This site meets the criteria for piloting VSF technologies, functionalities and enforcement strategies.

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The key factors in this decision included the highest level of commercial vehicle ADT and commodity flow among the corridors and roadway segments selected for review, proximity of the site to the Massachusetts border, accessible primary enforcement area, acceptable site geometry, and availability of power and fiber communications. The site is also suitable to test both escort and sorting enforcement strategies for further consideration at additional deployment sites.

A map of the VSF sites considered and the six existing weigh stations is shown in Figure 3.6.

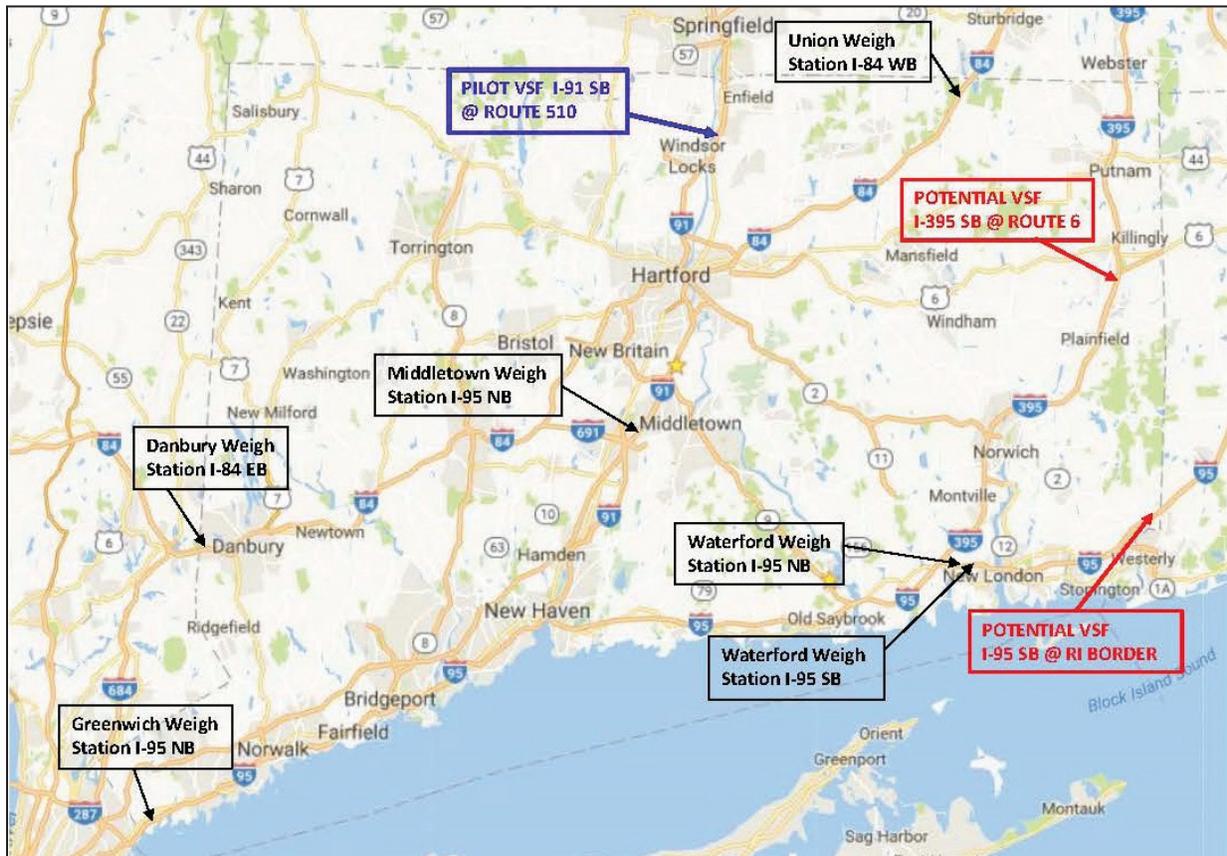


FIGURE 3.6. CONNECTICUT VSF SITES CONSIDERED AND EXISTING WEIGH STATIONS
(SOURCE: GOOGLE MAPS (2017))

The following technical documents for the pilot project roadway segment are on file and available from CTDOT

- I-91 Construction History: Exit 44 to Massachusetts State Line (50.77 – 58.00 mileage points)
- I-91/Route 510 Overpass: Connecticut Department of Transportation Plan for Rehabilitation of Bridges; List 4 Bridge Program in the Town of Enfield; Route 510; Project No. 48-153 Bridge No. 01275; Construction Completed: April 9, 1991
- Primary Direct Enforcement Area – Exit 42 Commuter Parking Lot: Connecticut Department of Transportation Plan for Commuter Parking Lot at Route 159 in the Town of Windsor Locks; Federal Aid Project No. I-91-3(133)49; Construction Completed: June 26, 1987

4.0 PROVEN FUNCTIONALITIES AND TECHNOLOGIES

The practice of commercial vehicle enforcement has evolved over the past 65 years. More recently, several states have adopted the use of new technologies and related functionalities for screening commercial vehicles and for direct enforcement activities. The growth in commercial vehicle travel is a byproduct of a combination of population growth, increased commodity consumption, goods and material production demographics, mobility, and just in time delivery.

Commercial vehicle enforcement personnel have not and will not be able to stop every truck that transports goods into, within and through Connecticut for direct enforcement. There is a gap between the volume of commercial vehicles/drivers that needs to be evaluated and the current enforcement personnel staffing level needed to positively change the behavior of commercial vehicles operating in Connecticut that choose to violate the law.

To help close this gap, proven technologies and related functionalities can be used to support, and more effectively and efficiently conduct, commercial vehicle enforcement operations. Screening commercial vehicles for enforcement evaluation on highways at highway speeds is a functionality that can be used to close this gap.

Functionalities for screening of commercial vehicles at highway speeds on the mainline have been used and proven for about 15 years. During this period, new functionalities have been tested in commercial vehicle enforcement operations. Some of these functionalities have been proven to perform in an accurate, repeatable and useful manner for commercial vehicle enforcement purposes, while others have not. The following is a list of proven functionalities:

- Automated Vehicle Identification
- Weigh-in-Motion
- Over Height
- Sorting

The potential benefits of roadside screening utilizing these functionalities include:

- Safer commercial vehicles traveling on the highway system with the potential to reduce crashes and related injuries and deaths
- Reduced pavement and bridge degradation
- Direct enforcement site footprint can be smaller and less costly to construct and maintain than fixed weigh stations. However, existing fixed weigh stations with technology/functionality improvements along with VSF development and mobile enforcement comprise a comprehensive enforcement program.
- Enabling commercial vehicles that operate in a safe and legal manner to bypass inspection stations saving time, fuel and operational costs

Each of these functionalities has the capability to support and focus enforcement personnel decisions on the selection of commercial vehicles that are screened for enforcement inspection and/or weighing.

4.1 AUTOMATED VEHICLE IDENTIFICATION

An Automated Vehicle Identification (AVI) system is used to collect commercial vehicle information while the vehicle is traveling at highway speeds on the mainline. Currently, there are three different types of AVI technologies, including the following:

- Cameras
- Cellular
- Transponders

Each of these AVI approaches has different processing times and requires different distances upstream of direct enforcement facility entry ramps/sites to work effectively. While none of the current AVI approaches provides 100% coverage or accuracy in identifying commercial vehicles, camera-based systems have the highest level of vehicle identification accuracy, at approximately 80% – 90%. Table 4.0 provides an overview of AVI technologies.

TABLE 4.0. AUTOMATIC VEHICLE IDENTIFICATION TECHNOLOGIES

	Cameras	Cellular	Transponders
Information Collected	License Plate # and/or USDOT#	CV Location	License Plate # and/or USDOT#
Estimated Percentage of Trucks Monitored	100%	10%	5% – 10%
Accuracy of System	80% – 90%	100%	100%
Cost	Agency installation and operation cost	User application cost	User transponder and use of proprietary system cost

4.1.1 Cameras

In the early 2000s, License Plate Reader (LPR) cameras and USDOT# reader cameras were tested and evaluated at lower speeds on weigh station ramps with limited success. However, the manufacturers/vendors of these products have continually worked to improve performance, accuracy and repeatability of these systems to identify commercial vehicles. As a result, and due to improved accuracy and reliability, LPR and USDOT# reader cameras have been adopted as a component of commercial vehicle screening systems in many states.

The license plate and USDOT# are placed in different locations on a tractor. The license plate is located on front bumper and the USDOT# is located on both sides of tractor. Thus, the orientation of each to the other is approximately 90°. Optimum placement of LPR and USDOT# reader cameras is 90° to each license plate and USDOT#. This would place the LPR camera over the centerline of each lane, aiming 180° from the direction of traffic flow, and the USDOT#

reader camera at the side of the outside (right) roadway lane, aiming 90° to the longitudinal axis of that lane. The maximum distance from the camera to the white right edge pavement marking should be no more than 30 feet. This will place the camera and camera pole in the clear zone with protection provided by a guardrail system. While optimum placement of the LPR camera is centered on the lane at 0° to the longitudinal axis, high accuracy can be achieved from 0° – 30° to the longitudinal axis of each lane's centerline. The maximum distance from the camera to the license plate should be no more than about 40 feet; the distance from the camera to the license plate may impact accuracy.

The commercial vehicle information gathered by AVI systems using cameras is then used to access systems that provide credential verification, safety scores and the date of the last enforcement inspection. Accuracy of camera-based systems will vary due to snow, mud and other debris covering the license plates and USDOT#s on commercial vehicles. It is the responsibility of the driver to keep this information readable at all times, to the extent practical operationally.

A disadvantage of AVI systems that use cameras to gather information is that commercial vehicle operators can disrupt the accuracy of the camera by putting black tape on license plates and/or USDOT#s to change the characters or by smearing mud on the numbers. However, the system can be configured to flag a non-read of an LPR or USDOT# of a commercial vehicle as potential violator.

LPR and USDOT# reader camera-based systems have been shown to accurately identify 80% – 90% of commercial vehicles.

4.1.2 Cellular

Around 2014, a new type of AVI utilizing a cellular smart phone application was introduced to the marketplace for commercial vehicle screening. This cellular-based system uses a “geo-fence” (a virtual boundary) to identify when a commercial vehicle enters the area. Once a driver activates the smart phone application, as the commercial vehicle travels through the geo-fence, information is exchanged between the system the application is connected with and the application. This results in a display notification on the application that provides the driver with either a red screen (*need for direct enforcement*) or green screen (*no direct enforcement is needed*). This AVI approach requires minimal roadside infrastructure. This cellular AVI approach is currently voluntary with only a small share of the market, but its use is growing in many states.

4.1.3 Transponders

Around 1997, states expressed interest in identifying commercial vehicles while in motion to support weight and height screening on entry ramps to fixed weigh stations. Transponders installed in commercial vehicles were the first type of AVI to be added as a component of roadside screening systems. This approach helped to identify commercial vehicles that were voluntarily enrolled in clearance programs. However, this approach is voluntary with participation representing only a very small percentage of commercial vehicles on the highway system.

4.2 WEIGH-IN-MOTION (WIM)

WIM systems have been used across the country for commercial vehicle enforcement on ramps into weigh stations, on mainlines upstream of weigh stations and as part of VSFs on the national highway system. These WIM systems have the functionality to measure and estimate some or all of the following: single axle weight; axle group weight; gross weight; internal bridge length; external bridge length; kingpin length; number of axles; number of axle groups; distance between axles; distance between axle groups; distance between commercial vehicles; speed of axles; commercial vehicle speed; imbalanced loads of wheel for each axle; and off scale operation.

Since the mid-1960s WIM technologies have been useful for traffic monitoring, establishing and revising pavement design standards, pavement and bridge management, and commercial vehicle weight screening. During this period, WIM technologies have rapidly grown in use and have evolved, with new technologies such as pressure sensors and strain gauges becoming available in the marketplace. Currently, three approaches are used for commercial vehicle weight screening on the mainline at highway speeds: load cells, bending plates, and piezoelectric sensors.

In the mid-1980s, states started building large direct commercial vehicle enforcement facilities with ramp WIM devices and sorting systems. At that time, many states' existing direct enforcement facilities were not equipped to process commercial vehicles fast enough to keep up with the ever-growing volume of such vehicles on highways served by these facilities. Thus, commercial vehicle queues extended onto the mainline, resulting in an unsafe environment for commercial vehicles and the motoring public. The addition of mainline and ramp WIM systems allowed commercial vehicles that were not near maximum weight limits to bypass the direct enforcement facility or return to the mainline, avoiding direct enforcement processes.

Typically, load cell-based systems were used from the introduction of ramp WIMs in the mid-1980s to the early 2000s. Operationally, ramp-based systems still required all commercial vehicle traffic to exit the mainline for ramp WIM screening. To help reduce facility footprint size, facility cost, the number of commercial vehicles required to exit the mainline, and related safety issues involving vehicle queueing onto the mainline, a WIM screening and sorting system was needed on the mainline upstream of the direct enforcement facility.

In the early 2000s, a piezoelectric WIM technology was tested and proven for use in the commercial vehicle enforcement environment for weight screening. Through the years, states installed piezoelectric systems on mainlines for new and existing direct enforcement facilities. This effectively reduced the number of commercial vehicles required to exit mainlines and enter direct enforcement facilities for weight enforcement.

Typically, for states that added mainline WIM systems at direct enforcement facilities, approximately 75% – 85% of commercial vehicles have been allowed to bypass these facilities, with the balance directed to enter the facility for processing. However, these values can be user definable and can be changed by having enforcement personnel modify screening threshold levels. Though this addresses the safety issue associated with commercial vehicles queueing back onto the mainline while still providing sufficient weight enforcement, the use of a WIM system does not address commercial vehicle and driver credentials, vehicle physical characteristics, and safety inspection issues.

As previously stated, WIM systems are currently used to screen commercial vehicles on the mainline and ramps. However, these systems are not legal for use as a direct enforcement tool. Improvements in WIM accuracy and repeatability over the past 30 years may make the use of WIM data for direct enforcement possible in the future. The NIST Handbook 44 (Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices, 2017) provides the standards for WIM systems. NIST is in the process of revising this handbook, including evaluating whether WIM devices can be used at low speeds as a direct enforcement tool in addition to their current use as a screening tool. If approved for use as a direct enforcement tool, the primary weight regulation function at commercial vehicle direct enforcement facilities could become a minor task and commercial vehicle safety inspection would become the primary task.

For a new WIM system installation or major modification of an existing WIM system, the contracting agency/owner specifies the calibration and test method and schedule that will be accomplished prior to final acceptance by the agency. The agency, in cooperation with the vendor, conducts this test on-site after the system has been installed or modified. Every WIM system is required to be recalibrated at least once per year as stated in ASTM 1318. The agency has the responsibility to recalibrate the WIM system no less frequently than annually and following any significant maintenance or relocation of the system. Sudden or unusual changes in data from the WIM system can also indicate the need for recalibration. In at least in some regions of the United States, such as the Northeast, the impact of weather conditions on pavement smoothness may negatively affect WIM system reliability and performance. The quartz piezoelectric technology is the only type of WIM system that does not require temperature compensation.

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TABLE 4.1. WIM TECHNOLOGIES OVERVIEW (SOURCE: COMPLIANCE COMPARATIVE ANALYSIS TECHNICAL REPORT: COMPREHENSIVE TRUCK SIZE AND WEIGHT LIMITS STUDY, FHWA, JUNE 2015)

	Load Cell Type Shown: Single	Bending Plate	Piezoelectric Type Shown: Quartz
Type of Measurement Technology	Strain-based	Strain-based	Pressure-sensitive
Typical in-pavement components per lane	2 platforms placed adjacent to each other; each 3'2" wide by 6' long	2 steel platforms placed adjacent to each other; each 2' wide by 6' long	8 sensors; 2 loops
Pavement Cut	Concrete vault: 38" deep by 58" wide by 165" long	For asphalt (vault installation): concrete foundation for frame support; cut and excavation pit 30" deep by 58" wide by 166" long	2.25" deep and 3" wide; with length adaptable for lane width
Installation Time	3 to 4 days	Vault installation: 3 days	Less than a day, includes curing time
Accuracy Range	6% of weight for 95% of trucks measured	10% of weight for 95% of trucks measured	10% of weight for 95% of trucks measured
Accuracy impacts	Can withstand weather extremes, but if incorrectly installed can create substantially more severe consequences to travelling public	Can withstand weather extremes, but if incorrectly installed can create substantially more severe consequences to travelling public	Pavement conditions (smoothness due to weather, rutting, plow damage, etc.)
Lifespan	Can be considerably longer than other types of WIM systems; However, service life can be impacted by condition of adjacent pavement due to non-smooth interface between load cell and surrounding pavement	~ 8 – 12 years	~ 6 years
Cost (total installed one lane) – does not include communications or traffic control costs	\$100,000 – \$150,000	\$55,000 – \$65,000	\$45,000 – \$60,000
Cost (additional lanes @ same site)	Not included in referenced source report	\$15,000 – \$20,000	\$15,000 – \$18,000
Cost Range: Annual Maintenance	\$12,600 – \$16,200	\$5,000 – \$5,900	\$4,100 – \$5,400

4.2.1 Load Cell

The load cell-based technology, a strain-based system, was the first type of WIM system proven and used for screening of commercial vehicles. When a load cell is properly installed, it performs with high accuracy and repeatability. There is a range of quality, longevity and robustness of load cell-based products available from several manufacturers. Estimated system cost and accuracy are referenced in Table 4.1.

A load cell is currently designed as an ASTM E1318-09, Type III system.¹³ It has the highest accuracy requirements at +/-6% gross vehicle weight of the three types of WIM systems. The actual accuracy of load cell-based systems has been proven to be +/-3-5% in practice. However, initially the maximum speed for this Type III WIM system was 50 mph. Thus, installations were limited to entry ramps at direct enforcement facilities. In 2004, the maximum speed for the ASTM E1318-02 Type III system was increased to 80 mph. This allowed Type III WIM systems to be used for commercial vehicle screening on the mainline with posted speed limits of up to 75 mph. This increase in the maximum specification speed eliminated the need for ramp WIM screening and supporting infrastructure and related costs at direct enforcement facilities.

A disadvantage of load cell-based and bending plate-based WIM systems is the impact on traffic during installation and construction. Load cell WIM systems require concrete sleeper slabs under them and concrete pavement slabs poured around them.

Thus, for the selected VSF pilot site, the existing asphalt and concrete base slabs would have to be removed for a length of 1,100 feet per lane; the WIM equipment location would need to be dug out for installation of the sleeper slabs; and entire control pavement area would need to be compacted to required density. WIM frames are then set in place and the concrete sleeper slabs are poured. After sleeper slabs have cured to a prescribed strength, then concrete control pavement can be poured. Typically, the control pavement is poured a little high and after some curing time, the finish is diamond ground to meet the smoothness requirements of ASTM 1318. This is a time-consuming process that can take three to five weeks per lane, not including weather days. Also, a temporary lane would be needed to minimize roadway capacity impacts through the construction area. Typically, commercial vehicle screening locations are strategically located in areas with high ADT levels, including commercial vehicles, thus impacting a high volume of traffic during construction.

4.2.2 Bending Plate

The bending plate type of WIM system is a strain-based system that was introduced about the same time as load cell-based WIM systems. Estimated system cost and accuracy are referenced in Table 4.1. When initially introduced, bending plate WIM systems did not maintain accuracy, nor the operational longevity experienced by load cell-based systems. Bending plate WIM systems were also used in ASTM E1318-02 Type III system environments. It is noted that bending plate WIM performance has improved, but reliability and longevity are still questionable. Installation and construction impacts are similar to those experienced with load cell-based systems.

13 <https://www.astm.org/DATABASE.CART/HISTORICAL/E1318-02.htm>

4.2.3 Piezoelectric Strips

Around 2004 the ASTM E1318-02 Type III system 50 mph maximum operating speed limit was upgraded to 80 mph. At that time, piezoelectric strips were being tested for use as a commercial vehicle enforcement screening sensor. Since 2004, primarily three different types of piezoelectric strips sensors have been used for commercial vehicle screening on mainlines and direct enforcement facility entry ramps. Piezoelectric strips sensors vary in size, shape, accuracy, cost and sensitivity to temperature changes. The three types of piezoelectric strips sensors in use include Piezo-Ceramic (PC), Piezo-Polymer (PP), and Piezo-Quartz (PQ).

Piezoelectric sensors are a group of pressure sensitive devices for weighing commercial vehicles in motion. Through the early years of development and refinement, piezoelectric WIM sensors provided a lower level of accuracy than load cell and bending plate WIM systems. PQ is the most accurate of the different types of piezoelectric technologies; temperature changes do not affect the accuracy of these sensors. They also have the highest overall performance among the three types of piezoelectric sensors.

PQ sensors are lowest in cost to purchase, install and maintain, as well as being easier to install and maintain as compared to load cell and bending plate type WIM systems. Therefore, Piezo-Quartz WIM systems are widely used as a component of commercial vehicle enforcement screening systems nationally.

4.3 OVER HEIGHT

Since the 1950s many tools have been used to check if commercial vehicles are over height, such as chains or bells hanging over the lane to a static scale at a defined height above the pavement. These systems did not notify enforcement personnel of potential over height issue. These basic types of over height systems required commercial vehicle enforcement personnel to witness the results of the operation of the system to effectively identify over height violations.

Physical features, such as overall height, length, and width, and loads of commercial vehicles are limited by codes and laws. In the mid to late 1980s, the only tools available to commercial vehicle enforcement personnel to evaluate compliance with regulations included fixed static scales and portable scales for weighing, and handheld tape measures to measure physical limits of commercial vehicles. Currently, the physical features of a commercial vehicle can be evaluated, estimated and screened while the vehicle is in motion up to ramp speeds of 45 - 50 mph. This information can be used as an aid to identify commercial vehicles that are potentially in violation of regulations, but it cannot be used for direct enforcement.

4.3.1 Light Beam Break

Presently, the primary approach used for over height vehicle detection is light beam break technology.

4.4 ESCORTING

Escorting commercial vehicles from a mainline to a direct enforcement site is always an option when warranted. This strategy combines the benefits of VSF technologies/functionalities, and enforcement personnel training and experience to visually screen trucks for issues that VSF E Screening technologies cannot address. Such issues might include a broken brake line, inoperable lights, loose load securement, and driver weaving, among others.

4.5 SORTING

In the late 1980s, states were building large direct commercial vehicle enforcement facilities that incorporated ramp WIM and sorting system functionalities. At that time, a red or green signal with arrows was used to sort commercial vehicles through direct enforcement facilities in a commercial vehicle-only environment. However, with commercial vehicle screening being conducted on the mainline in a mixed traffic environment of commercial and non-commercial vehicles, a different approach was needed.

Dynamic Message Signs (DMS) and passive signage are appropriate tools for sorting commercial vehicles from a mainline to a direct enforcement site by placing the signage upstream of the VSF. DMS are electronic message signs that can display a variety of messages, whereas passive signage is a sign with a fixed printed message.

DMS are used to direct commercial vehicles to the right lane ("TRUCKS USE RIGHT LANE") when enforcement personnel are using the VSF system for enforcement. Inductive loops are installed upstream of each DMS so that the message can be changed for each commercial vehicle based on the results of analysis of data collected, thus directing a vehicle to a direct enforcement site or allowing the vehicle to bypass the site. When the VSF is not in use, the signage is blank and commercial vehicles can travel on any allowable lanes. An ancillary benefit of the use by DOTs of DMS on the mainline is enhanced intelligent transportation system functionality when a sorting strategy is not in use by enforcement personnel.

Passive signage ("TRUCKS USE RIGHT LANE") requires all commercial vehicles to use the right lane at all times through a segment of roadway.

Factors used to determine the type of signage used for sorting include ADT and level of commercial vehicle traffic, frequency of operation of the VSF, and cost, among others. For some installations a combination of DMS and passive signage may be appropriate.

5.0 APPROPRIATE FUNCTIONALITIES AND TECHNOLOGIES FOR THE VIRTUAL SCREENING FACILITY PILOT PROJECT

The selected VSF E-Screening pilot project site is located on I-91 southbound at the Route 510 (Depot Hill Road) overpass approximately 200 feet upstream of the overpass. The length of the site's control pavement for WIM deployment will be 1,100 feet. The end of the control pavement will be 100 feet north of the northerly side of the Route 510 overpass. The WIM system will be located 100 feet upstream (north) from the end of the control pavement, with 1,000 feet of control pavement provided upstream of the WIM system. This segment of roadway is straight, with no vertical or horizontal curves. The current finish pavement type, Superpave asphalt, is in good condition and mostly smooth, and has a concrete slab base material for the outside two lanes. Table 5.0 provides a summary of the pavement type in this section of the highway at the proposed VSF site.

TABLE 5.0. PAVEMENT TYPE SUMMARY: VSF HIGHWAY SECTION

Number of lanes in one direction	3
Current finish pavement type (Flexible/Superpave/Hot Mix Asphalt ?)	Hot-mix asphalt (flexible), Superpave Design Level 3 (100 gyrations N_d); Hot-mix asphalt base in high-speed (left) lane, 9" Jointed Reinforced Concrete Pavement in center and right lanes (40' slab length, doweled transverse joints)
Pavement depth (Asphalt)	5" at edges of concrete lanes; approximately 6.5" to 7" at crown (crown is between right and center lanes)
Base material (Concrete slab for outside two lanes)	9" Jointed Reinforced Concrete Pavement in center and right lanes (40' slab length, doweled transverse joints) for right and center lanes; 9" Hot-Mix Asphalt (1.25" top-size aggregate base mix, 'Class 4' Marshall mix) high-speed lanes
Base depth (Outside two lanes and inside lane)	9" all lanes
Subbase material	"Subbase" (well-draining, non-frost-susceptible gravel (natural or manufactured)) under Right Shoulder, right lane, center lane; "Processed Aggregate Base" (well-draining, non-frost-susceptible crushed-aggregate manufactured gravel) under high speed lane and left (inside) shoulder
Subbase depth	10" typical (as taken from 1958 plan cross-sections and following typical CTDOT design practice at the time; not shown on typical cross-sections) on right and center lanes; 10"- 13" Processed Aggregate Base typical (as taken from 1991 widening plans, no typical values indicated but 13" minimum on inside shoulder in earth cuts and fills)
Edge drains	None
Seasonal high water elevation to finish pavement	To be determined
Age of existing roadway pavement (Early in Life Cycle, ??? years)	NB top 3" (2" HMA 0.5 Nominal Maximum Aggregate Size, dense-graded Superpave 100 gyration mix on 1" (typical) 0.25" nominal maximum aggregate size 75 gyration mix dense-graded mix) placed in 2014; SB top 3" (same mix and lifts as NB) placed in 2015
Longitudinal slope	Less than 2%
Cross slope	Less than 3%

As previously discussed in Section 3.2.2.1, this site is approximately six miles south of the Massachusetts border and approximately three miles north of the proposed direct enforcement pull-off site, at the Park and Ride facility at Exit 42. An ADT data sample for 1/17/17 and 1/18/17 shows current peak hour truck volume of 375 per hour. The 2017 CTDOT Statewide Travel Model estimates a 17% ADT growth from 2015 - 2040; this represents an increase of 64 trucks per hour for a total of 439 trucks per hour, which will be used as the commercial vehicle design hourly volume for the VSF pilot project.

Recorded environmental conditions for this site are

- Altitude: approximately 59' MSL
- Average temperature range: 16°F - 84°F
- Location: 45 miles from the Long Island Sound coast
- Average annual rainfall: 44.23"
- Highest sustained winds: 70 mph with gusts of up to 89 mph
- Average annual snowfall: 40.5"

It is expected that on an infrequent basis, some environmental conditions typically experienced in Connecticut will negatively impact the performance accuracy of some VSF system functions. These include

- Snow cover affecting pavement smoothness and WIM accuracy for weighing vehicles
- Salt spray from winter highway maintenance operations affecting readability of LPR and USDOT# reader camera images for identifying vehicles

This aspect of system performance should be monitored and tested during the implementation phase of the pilot project.

Pilot project VSF site E-Screening functionalities needed for screening commercial vehicles include

- Automated Vehicle Identification
- Weigh-in-Motion
- Over Height Detection
- Escort and Sorting
- Classification Count Devices

5.1 AUTOMATED VEHICLE IDENTIFICATION

Automated Vehicle Identification (AVI) is a function that collects commercial vehicle information while the vehicle is in motion. The most appropriate AVI functionalities for this pilot project include LPR, USDOT# reader, and overview cameras.

Camera-based AVI systems gather information that includes credential verification, a safety score and the date of the last vehicle inspection, among others. These camera-based systems have been proven to accurately identify 80% - 90% of commercial vehicles in good to moderate weather conditions.

LPR and USDOT# reader cameras require a strobe to illuminate the commercial vehicle during low light conditions. Currently, non-visible illuminating strobes have been proven to be safe, effective, and reliable. Typically, these strobes are separate from the cameras; for best results, the camera and corresponding strobe will need to be located near each other, preferably over or under each other. In-pavement inductive loops are typically used to trigger these cameras and strobes. When a commercial vehicle traveling in a lane covers the inductive loops, the overview camera will be triggered to take a picture that is then delivered electronically to enforcement personnel.

5.2 WEIGH IN MOTION

Table 4.1 provides a comparison of the different types of WIM technologies considered for the pilot project. The factors cited – including installation time, accuracy range and impacts for screening vehicles, projected lifespan, projected cost and annual maintenance expense, along with the type of finish pavement and base material – were analyzed in identifying the type of WIM system for the pilot VSF site. The piezoelectric-quartz technology is preferred for this project. Key considerations in this determination included

- Minimal installation time, along with least disruption to the traveling public during construction. Similarly, least disruption anticipated for in-road system repairs/replacement.
- Acceptable accuracy range and impacts for the purpose of screening vehicles.
- Lowest projected cost and annual maintenance expense, as well as possibly life-cycle cost.
- Construction issues with installation of other types of WIM technologies due to concrete slab base material on outside two lanes of the highway, as well as need for a temporary travel lane in this high-density travel area.

5.3 OVER HEIGHT DETECTION

The most appropriate over height detector for this pilot project is the light beam break technology.

These devices are proven, rugged, reliable, and simple. There are minimal parts to install and maintain. Typically, light beam break devices are installed 3" – 6" above the legal commercial vehicle height limit. This enables truck and trailer suspension movement up and down preventing a false positive response. These devices are typically mounted on breakaway poles about 13'-9" to 14'-0" above finish pavement height. At these heights it is unlikely that snow from plowing operations or other debris will cover the devices, impacting their operation. Each integrator may have a preference as to where this device is installed at the VSF site.

5.4 ESCORTING

Both escorting and sorting enforcement strategies can be effective for routing commercial vehicles from a mainline to a direct enforcement site. The volume of commercial vehicle traffic and visibility of enforcement activity are among the factors used to select the strategy that is best suited for a specific roadway segment. Typically, with the same level of enforcement staffing, throughput of commercial vehicles selected for enforcement examination will be higher for the sorting strategy than the escort strategy. These strategies were assessed by CTDMV, which decided to plan the pilot project using the escort strategy only.

5.5 CLASSIFICATION COUNT DEVICES

The appropriate Classification Count Device for this pilot is an in-pavement inductive loop technology. This technology has been proven through decades of use in all types of environments; the design is simple, with minimal parts to install and maintain. These loops can be installed within just a few hours, during nighttime to minimize impacts to interstate traffic. The sensitivity level of loops is determined by size and number of turns (loops) for each loop. The project integrator should identify the size and number of turns for their system's sensitivity needs for system design. Two inductive loops are needed per lane to classify vehicles in traffic flow.

6.0 SMART ROADSIDE INITIATIVE TECHNOLOGIES DEPLOYED BY STATES

6.1 US FEDERAL PRACTICES THAT MOLDED STATE COMMERCIAL VEHICLE ENFORCEMENT PROGRAMS

From a federal perspective, protecting the traveling public and preserving highways and bridges is highly important and goes back to the enactment of the Federal-Aid Highway Act of 1956. This act authorized the Interstate and Defense Highway System. State and federal highway agencies are responsible for managing the disbursement of billions of dollars invested in highway infrastructure each year. FHWA is responsible for certifying state compliance with federal standards. FHWA also assists states with policy questions, clarifications, reporting requirements, training, and research. States must ensure that commercial vehicles comply with federal safety, size and weight regulations to accomplish these goals.

6.2 USE OF TECHNOLOGY FOR ROADSIDE ENFORCEMENT FROM THE FEDERAL VIEW

6.2.1 Use of Technology for Roadside Enforcement from the Federal View

A recent national examination of mainline motor carrier screening operations in the United States, the "Smart Roadside Initiative (SRI) Gap Analysis: State of the Practice,"¹⁴ was completed in March 2014. The SRI is a USDOT initiative designed to break down barriers between roadside Intelligent Transportation Systems (ITS) data storage environments in order to improve motor carrier safety, mobility, and the operational efficiency of both commercial vehicle freight carriers and public-sector agencies. The study's goals were to

- document currently available and emerging roadside technologies for Commercial Vehicle Operations (CVO);
- analyze the functionalities being developed as part of the Smart Roadside Prototype; and
- identify gaps where functionalities are absent or insufficient to support the SRI.

The focus of the study was on functionalities and technologies associated with three operating scenarios:

- Mainline screening
- Virtual weigh stations
- Commercial parking systems

14 FHWA-JPO-14-130

The SRI studied seven states throughout the nation for best practices and identified three major trends:

1. **Multiple functionalities and technologies** are currently implemented and used at VSFs. One of the technologies that has increased in usage in many states is transponders integrated with WIM systems. Transponders have limited interoperability between transponder systems and only a small percentage of the motor carrier industry has bought into these branded systems.
2. **Integration of functionalities and technologies.** VSFs employ several types of technologies that must be integrated in order to communicate with each other to achieve improved enforcement efficiency and effectiveness. The integration of functions is needed not only within a VSF, but also between VSFs and fixed weigh stations.
3. **Use of technology to reduce cost per truck** for statewide commercial vehicle enforcement, through additional VSFs. VSFs and mobile enforcement require fewer personnel and less costly infrastructure than traditional fixed enforcement facilities that require all trucks to enter for inspection.

Table 6.0 provides information on the types of electronic data system participation by states based on information compiled by FMCSA15, including the following categories of participation:

- Participates in Electronic Screening: states that participate in one of the nationwide e-screening enrollment programs such as PrePass, NORPASS, Drivewyze, or a state-operated program.
- Exchanges Registration Data with SAFER (Safety and Fitness Electronic Records): states that currently upload vehicle registration data to SAFER. Registration data are needed to support manual or electronic roadside screening. Uploading credential data to SAFER should be an urgent priority of each state.
- Uses E-Credentialing: states in compliance with the e-credentialing requirement of Core Innovative Technology Deployment (ITD). A requirement of Core ITD is deployment of automated electronic processing of at least International Registration Plan (IRP) and International Fuel Tax Agreement (IFTA) credentials from a carrier to the state via web-based or computer-to-computer solutions. Alaska and Hawaii are exempt from this requirement.

15 <https://www.fmcsa.dot.gov/information-systems/itd/itd-deployment-status>

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TABLE 6.0. TYPES OF ELECTRONIC DATA SYSTEMS USED BY STATES
(SOURCE: FMCSA, ITD DEPLOYMENT STATUS)

State	Participates in Electronic Screening	Exchanges Registration Data with SAFER	Uses E-Credentialing
Alabama	x	x	x
Alaska	x	x *	x *
Arizona	x	x	x
Arkansas	x	x	x
California	x	x	x
Colorado	x	x	x
Connecticut	x	x	x
Delaware	x	x	x
Florida	x	x	x
Georgia	x		
Hawaii			
Idaho	x	x	x
Illinois	x	x	x
Indiana	x	x	x
Iowa	x	x	x
Kansas	x	x	x
Kentucky	x	x	x
Louisiana	x	x	x
Maine	x	x	x
Maryland	x	x	x
Massachusetts	x	x	x
Michigan	x		x
Minnesota	x		x
Mississippi	x	x	x
Missouri	x	x	x
Montana	x	x	x
Nebraska	x	x	x
Nevada	x		x
New Hampshire	x		
New Jersey	x	x	x
New Mexico	x	x	x
New York	x	x	x
North Carolina	x	x	x
North Dakota			x
Ohio		x	x
Oklahoma	x	x **	x
Oregon	x	x	x
Pennsylvania	x		
Rhode Island	x	x	
South Carolina	x	x	x
South Dakota	x	x	x
Tennessee	x	x	x
Texas	x	x	x
Utah	x	x	x
Vermont	x		
Virginia	x	x	x
Washington	x	x	x
West Virginia	x		x
Wisconsin	x	x	x
Wyoming	x	x	
(*) : IRP and IFTA Exempt (Alaska)			
(**) : IRP Only (Oklahoma)			

6.3 SELECTED BEST PRACTICES

The agencies responsible for statewide commercial vehicle enforcement vary from state to state. Many states assign the capital responsibilities to their transportation agency, while enforcement operations are controlled by the state patrol/police. Some have specific joint units responsible for the entire commercial vehicle enforcement program, while others assign size and weight responsibilities to the department of transportation and operational safety to the state patrol/police.

6.3.1 *Direct Enforcement*

A mature statewide commercial vehicle enforcement network will not only ensure that fixed facilities and mobile enforcement sites are operated at high volume commercial vehicle corridor locations, but will also utilize technology to maximize the efficiency of resources. An effective statewide enforcement network will also provide operational flexibility that enables fixed facility and mobile enforcement operations to work together in support of each other. One primary goal of VSFs is that only commercial vehicles potentially in violation of regulations and laws should be impacted by enforcement operations.

The challenge for most states is maximizing the ability to accomplish these objectives over an expected period of projected growth in the number of commercial vehicles traveling on state roadways, and related costs required to deploy and maintain the infrastructure, technology, and personnel needed to be effective. Current commercial vehicle enforcement trends used by states are

- use of multiple technological applications to identify commercial vehicles;
- integration of technologies is critical to operational efficiency; and
- deployment of VSFs for screening commercial vehicles selected for enforcement.

6.3.2 *States*

Several states that have deployed various smart roadside technologies to support commercial vehicle enforcement were selected as examples based on the CASE Study Manager's experience and knowledge from information gathered from numerous presentations, conferences and interviews, and presentations by states to the CASE Study Committee.

6.3.2.1 FLORIDA

Florida uses a strategic approach for the placement and type of facility needed for each fixed facility and mobile enforcement pull-off location. Contributing factors in deciding where a direct enforcement site could be located include the volume of commercial vehicle traffic, accident history in the roadway segment, highway type, past mobile enforcement history, available right-of-way and ease of bypass around the potential site.

The primary considerations for determining a direct enforcement location are commercial vehicle volume and availability of enforcement personnel. Once the direct enforcement location is identified, a determination is made regarding the type of facility that is needed to efficiently and effectively change negative behavior of the commercial motor carrier industry

using this segment of the highway. Florida uses a combination of tools for commercial vehicle enforcement and several types of facility combinations to maintain a statewide presence and to help promote a level playing field for the trucking industry throughout the state. These facility types (by approximate increasing physical size and capabilities) include the following:

- Small improved pull-off area and use of portable scales for weighing vehicles
- VSF with Law Enforcement Officer (LEO) escort of suspect commercial vehicles to a non-improved area¹⁶ and use of portable scales for weighing vehicles
- VSF with LEO escort of suspect commercial vehicles to an improved area and use of portable scales for weighing vehicles
- VSF with LEO escort of suspect commercial vehicles to an improved area and use of fixed static scales for weighing vehicles
- VSF with Dynamic Message Signs (DMS) that directs suspect commercial vehicles to an improved area with fixed static scales for weighing vehicles and no buildings
- VSF with DMS that directs suspect commercial vehicles to an improved area with fixed static scales for weighing vehicles and a small building for commercial vehicle operators that is operated remotely
- Weigh station with passive signage that directs 100% of commercial vehicles to an improved area when it is open, with fixed static scales for weighing vehicles, a few truck parking spaces, and a medium size building for staff and commercial vehicle operators; some of these serve both directions of travel
- VSF with DMS that directs suspect commercial vehicles to an improved area with fixed static scales for weighing vehicles, a few truck parking spaces, and a medium size building for staff and commercial vehicle operators
- VSF with DMS that directs suspect commercial vehicles to an improved area that serves both directions of travel with fixed static scales for weighing vehicles, a few truck parking spaces, and a medium size building for staff and commercial vehicle operators
- VSF with DMS that directs suspect commercial vehicles to an improved area with two fixed static scales for weighing vehicles, a large truck parking area, large size building for staff and commercial vehicle operators, and an inspection building with a comfort station

All but two of these direct enforcement approaches use VSFs to minimize the footprint size of the facility and personnel needed for effective operations. Florida is currently adding VSF technologies/functionalities to some of their existing weigh stations that currently require all commercial vehicles to enter the station. These functions will reduce the volume of commercial vehicles required to enter these weigh stations from 100% to only about 15% - 20%. Florida's VSFs use the following functionalities:

- Automated Vehicle Identification (AVI): Cellular-based (Drivewyze); LPRs; Transponders (PrePass); and USDOT# readers

¹⁶ As referenced, a "non-improved area" is any location used by enforcement staff to conduct direct enforcement that has not been improved, such as a breakdown lane or highway shoulder

- WIM Systems: Quartz Piezoelectric Strips (on mainlines); and Load Cell (on ramps into weigh stations)
- Overview Cameras
- Computers (to send and receive data)
- DMS at VSFs with medium to high truck volume

6.3.2.2 KENTUCKY

Kentucky developed its own Kentucky Automated Truck Screening (KATS) System. Its purpose is to identify commercial vehicles that are potentially in violation of federal or state vehicle codes. VSFs developed as part of KATS are equipped with the following functionalities:

- AVI: LPR; and USDOT# readers
- WIM sensor
- Overview Camera
- Others including: Triggering Mechanism; Lighting; Tracking/Notification System; and Surveillance/Parking Cameras

The primary technology used for AVI is cameras designed to read license plates on the front of commercial vehicles and USDOT# on the side of a tractor. This camera-based system is not as accurate as the transponder-based system, but the KATS system attempts to screen all trucks. The USDOT# readers are about 70%-75% accurate, while LPRs are about 80% accurate. The accuracy varies from site to site depending on the setup. When utilizing these camera-based systems, enforcement personnel verify that the data output from the camera-based system is correct. If not, enforcement personnel can key in the correct data and re-screen the vehicle.

Currently, Kentucky has deployed KATS at 14 sites within the state and at its borders. One additional VSF is planned and funded but not deployed. This approach allows the statewide system to screen both interstate trucks traveling through the state, and intrastate trucks traveling within the state.

KATS utilizes a personalized version of the Iteris CVIEW (Commercial Vehicle Information Exchange Window)¹⁷ as the center hub for information exchange. Information is gathered from many sources: smart roadside data from commercial vehicles, KATS centralized clearinghouse, and many other external clearinghouses. Integration of these data sources can be complex. This data exchange system architecture is depicted in Figure 6.0.

¹⁷ CVIEW is a state system that collects information from the commercial vehicle credentialing and tax systems to generate portions of the interstate carrier, vehicle, and driver snapshots and reports for exchange within the state (e.g., to roadside sites) and with the SAFER system.

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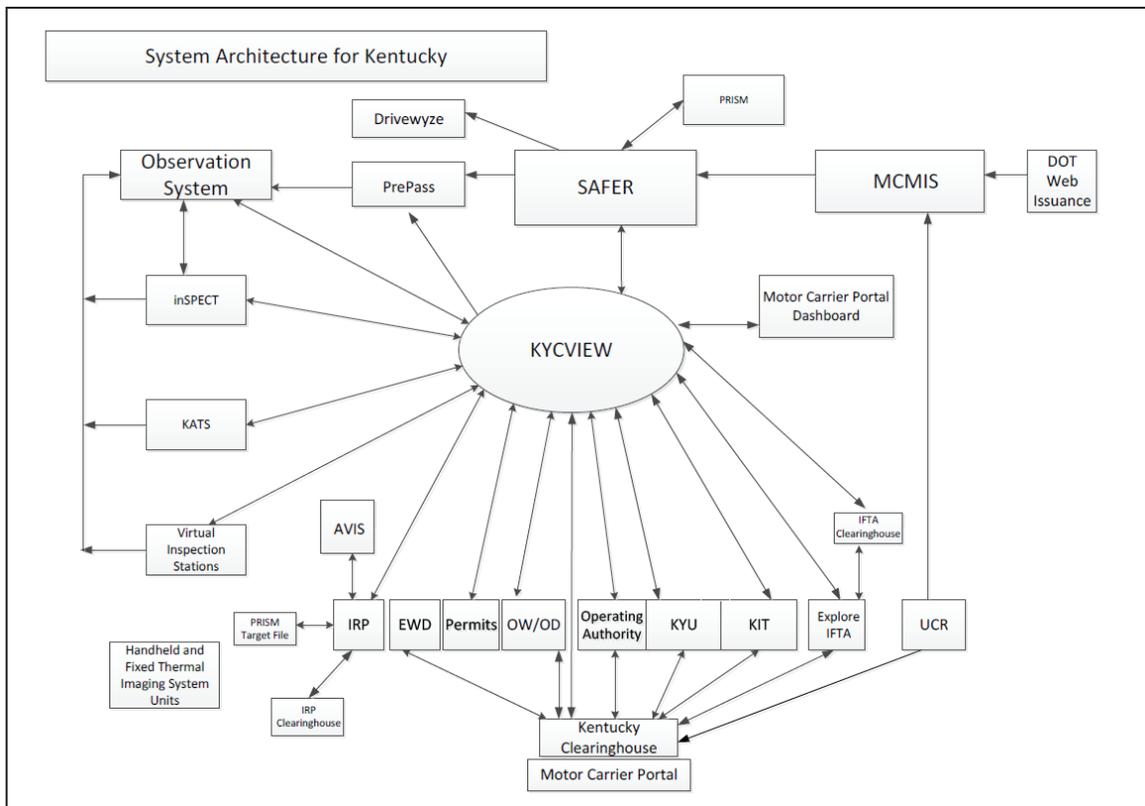


FIGURE 6.0. SYSTEM ARCHITECTURE FOR KENTUCKY (SOURCE: KENNEDY TRANSPORTATION CENTER, UNIVERSITY OF KENTUCKY; PRESENTATION TO CASE STUDY COMMITTEE BY JENNIFER WALTON, PE; 1/27/17)

As commercial vehicles pass through a KATS system, commercial vehicle data is collected. The KYCVIEW evaluation tool analyzes this data against data from multiple clearinghouses. The result of this process is divided into one of four categories:

1. All tests passed
2. Some information not available – pass on all tests that could be run
3. At least one test failed – truck not directed to pull in
4. At least one test failed – truck directed to pull in

Kentucky uses several decision factors to determine the best location for a VSF:

- Volume of truck traffic
- Crash rates
- Bypass to a facility
- Ability for enforcement to intercept the truck
- Area where trucks can be pulled off the roadway
- Geometry of the roadway

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- Pavement condition
- Availability of utilities
- Construction plans
- Manpower
- Support of the local court system

Lessons learned from the process of developing and deploying KATS VSFs in Kentucky are shown in Table 6.1.

TABLE 6.1. LESSONS LEARNED IN THE DEVELOPMENT AND DEPLOYMENT OF KATS VSFs IN KENTUCKY
(SOURCE: KENNEDY TRANSPORTATION CENTER, UNIVERSITY OF KENTUCKY; PRESENTATION TO CASE STUDY COMMITTEE BY JENNIFER WALTON, PE; 1/27/17)

Lesson Learned	
Make sure enforcement is involved and informed	<ul style="list-style-type: none"> – Input into site location/design of system – Informed on the capabilities of the technology
Encourage/require enforcement to strategize on how virtual sites will be utilized	<ul style="list-style-type: none"> – Include administration, supervisors, and road officers
Make sure you communicate your project to all the key stakeholders	<ul style="list-style-type: none"> – Maintenance/construction projects may impact your project!
A USDOT# reader will get you more information (even with lower accuracy rates)	<ul style="list-style-type: none"> – License plate data is available for some states and not available for any Canadian provinces – License Plate data is often tied to the wrong US-DOT# – States often have faulty information about the plate in SAFER
Addressing data quality issues will need to be a part of your maintenance plan for the system	<ul style="list-style-type: none"> – Kentucky developed an “Ignore Table” for states who provide “bad” license plate data – Give enforcement the ability to “turn off” and “turn on” some tests
Stricter regulations are needed for the USDOT# (appearance and placement) on the side of commercial vehicles	
Data from the system is useful even if enforcement doesn't stop every potential violator	<ul style="list-style-type: none"> – Division of Road Fund Audits, Kentucky Transportation Cabinet utilizes data for observations – Enforcement can utilize the data for scheduling
Cellular modems expand the range of installations	
Utilities/guardrail can take a long time to get installed	
Locating equipment on a ramp can be tricky	<ul style="list-style-type: none"> – Want as much time as possible for the Optical Character Recognition (OCR) processing – Want to give trucks some time to slow down before capturing images
Locating equipment for a virtual installation	<ul style="list-style-type: none"> – Need to ensure adequate room to make enforcement stops

Kentucky's KATS is a robust commercial vehicle VSF system that has integrated multiple agencies and stakeholders into the development process. This cross agency and cross disciplinary team evaluated the needs of all stakeholders and developed a solution that seems to work well for them.

6.3.2.3 MAINE

Maine has two primary weigh stations, I-95 Kittery Southbound and I-95 York Northbound, with e-screening capabilities. It is noted that the screening functionalities at the York facility include the following:

- AVI: Cellular-based system (Drivewyze); LPR; USDOT# reader
- WIM Sensors
- Thermal Brake Check
- Hazmat Placard Reader

Hazmat placard screening is a newer functionality that is used to evaluate the type and safety risk of the load being transported. This screening functionality is deployed at a few commercial vehicle enforcement screening facilities throughout the country.

6.3.2.4 MARYLAND

Maryland identified a need for commercial driver hours of service information. As a result, in 2015 Drivewyze demonstrated their e-inspection program in Maryland. This program was able to establish commercial driver compliance with hours of service requirements without sending actual log details. Currently, Maryland has 27 Drivewyze equipped facilities equipped with this functionality, as well as the following functionalities:

- Cellular device (for communications and AVI)
- GPS in cellular device (for location)
- Geo-fence (to define virtual screening area)
- Web-based computer (to send and receive data)

6.3.2.5 MONTANA

Montana uses a State Truck Activities Reporting System, referred to as STARS, comprised of data collection sites that provide WIM and vehicle classification data. STARS was piloted in the early 2000s. Initially, STARS data were not available to Montana's commercial vehicle enforcement personnel for use in real time. Data from this system are analyzed and used to focus future commercial vehicle enforcement on roadway segments in the state that have the greatest amount of pavement damage from overweight commercial vehicles. Currently, Montana Highway Patrol can access STARS in real time to assess commercial vehicle weights and traffic volumes and deploy mobile enforcement personnel to intercept potentially overweight commercial vehicles for enforcement inspection.

6.3.2.6 NEW YORK STATE

In New York, commercial vehicle enforcement is the responsibility of two agencies: New York State Police and the New York State Department of Transportation (NYSDOT). These agencies work in a coordinated effort to strategically conduct safety and size and weight

enforcement using a mobile commercial vehicle enforcement approach with inspection sites located throughout the state. New York State, as well as Nevada, are the only two states in the 48 continental states that do not use fixed facilities for commercial vehicle enforcement. New York State ITD/CVISN E-Screening Program has five primary objectives: safety, economics, environmental, energy, and sustainability.

- Safety – screen more commercial vehicles and gather better information for enforcement of commercial vehicles and commercial drivers. This is accomplished by identifying potential non-compliant commercial vehicles, which produces a higher probability of stopping commercial vehicles with size, weight and/or safety issues.
- Economics – achieve improved compliance through a more efficient and effective roadside enforcement approach to reduce public sector asset management and operating cost; level the playing field for competitiveness and achieve lower operating costs for commercial motor carriers; and reduce delays to increase reliability of freight deliveries.
- Environmental/Energy/Sustainability – reduce motor carrier emissions, fuel consumption, vehicle wear and tear, and overall operating costs.

The New York E-screening program was developed with three desired outcomes:

- Use available technology to gather more and better commercial vehicle data
- Develop information to direct and support planning, asset management, operations, and enforcement of commercial vehicles
- Utilize available data to achieve more efficient and effective decisions to improve size, weight and safety for commercial vehicle enforcement

Currently, New York's statewide E-screening facilities include six sites that are operational and one that is scheduled for construction in the spring of 2018. The following functionalities are utilized at these sites:

- AVI: Cellular-based system (Drivewyze); LPR; USDOT# reader; and Transponder reader (Norpass)
- WIM sensors: Bending Plates, Load Cells, or Quartz Piezoelectric Strips
- Over height detection

New York State's Office of Information and Technology Services developed a screening system "dashboard" application for the state's commercial vehicle enforcement program. This system enables data mining for statistical and trend information for motor carrier audits and assists commercial vehicle enforcement operations (when and where to focus enforcement efforts) to better inform commercial vehicle enforcement strategies. New York City DOT and the Port Authority of New York/New Jersey have direct access to the Alexander Hamilton Bridge application. NYSDOT also provides traffic data to these two agencies from the department's planning WIM sites in the New York City area. NYSDOT's Office of Policy and Planning also provides queried data, not just raw data, to these agencies from the Dashboard Application on an as needed basis.

Additionally, the three agencies are in regular contact and hold meetings every two months to

- share data and enforcement strategies (mainly administrative, i.e., sending “warning” letters to frequent violators); and
- discuss issues related to completion of the NYS freight plan and progress on NYSDOT’s oversize/overweight credentialing system.

6.3.2.7 OKLAHOMA

Oklahoma has the most advanced E-permit screening system in the country. Currently, only one weigh station is operating with this functionality as a prototype of how an E-permit bypass system can operate. The E-permit system automatically screens trucks on the mainline for their dimensions and weight and compares this data against E-permit tables.

6.3.2.8 OREGON

Oregon established the Oregon Motor Carrier Transportation Advisory Committee (MCTAC) to help alleviate issues between state agencies. MCTAC consists of allied transportation associations, and serves as a problem solving and regulatory discussion group.

Also, Oregon DOT (ODOT) and Washington State DOT (WSDOT) have developed a cooperative interstate relationship that includes interoperability between ODOT’s Green Light program and WSDOT’s Norpass. Additionally, Oregon, Washington State, and Idaho have an agreement for conducting special commercial vehicle enforcement exercises.

6.3.2.8 WASHINGTON STATE

Washington State has an established history with Norpass transponder use. The use of this technology continues to spread in Washington. However, saturation of the commercial vehicle market is small. They are looking into other types of AVI systems to increase the saturation of commercial vehicle screening.

6.3.3 Functionalities Deployed by States

An overview of the functionalities deployed by various states is provided in Table 6.2. Use by states of each functionality identified is intended to show the general level of penetration of use throughout 50 states. Information gathered for this table was based on the CASE Study Manager’s experience and knowledge through numerous reports, presentations, conferences and interviews.

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SMART ROADSIDE INITIATIVE TECHNOLOGIES DEPLOYED BY STATES

TABLE 6.2. FUNCTIONALITIES DEPLOYED BY VARIOUS STATES

Functionality	Description	Use by States
Weigh-in-Motion (WIM)	Measures axle weight and distance between axles for each truck travelling over WIM in-pavement sensors	Most states use WIM sensors in conjunction with some form of AVI
Automated Vehicle Identification (AVI)	Using transponders, cameras or cellular-based technology, queries databases for commercial vehicle credential and safety information	Most states use some form of AVI; many in conjunction with some type of WIM system
Over Height Detection and Dimension-in-Motion (DIM)	Measures height of each truck and some devices can measure height, width, and length	Most states use some type of over height detection device either on the mainline or at fixed facilities. Florida also uses 3d measuring devices at all interstate weigh stations
Classification System	Identifies truck class as one of 13 FHWA standard classes	States typically collect classification data for planning
Automatic Image Device	Reads license plate, USDOT#, or takes overview picture of tractor to help uniquely identify commercial vehicles	Most states use these devices and more states are considering them for implementation and use to supplement or provide AVI
Brake Check System	Measures thermal contrast between commercial vehicle brake systems	Only a few states use these systems on a regular basis. These systems can be labor intensive to operate. Maine is one northeastern state that uses this system.
Data Linking	As commercial vehicles move between direct enforcement sites/stations, individual truck information is time stamped and available at other sites/stations	Only a few states use data linking between states. Oregon is one of the leaders in use of data linking
Bypass Warning	An automatic image device or AVI is used to identify commercial vehicles directed to report to a direct enforcement site/station that remain on the mainline	Most states with mainline screening facilities incorporate this functionality near the gore into direct enforcement sites/stations

6.3.4 Functions and Operations

There is a tradeoff between enforcing commercial vehicle size, weight and safety regulations to a high standard and impacts on trucking industry motor carriers that operate within these standards. Strategies to find a balance between enforcement and impacts include

- Identifying as many potential violating commercial vehicles as possible at a reasonable cost to the enforcement agency and the motor carrier industry;
- Providing enforcement personnel and commercial drivers with a physical location sufficiently sized to allow efficient flow of commercial vehicles through the area with enough space for weight and safety inspections without negatively impacting others;
- Providing enforcement personnel with efficient access to virtual screening information and the ability to configure and vary automated bypass criteria as needed;
- Providing enforcement personnel with a working environment which allows them to safely and efficiently interact with commercial vehicle drivers and their corresponding vehicles without negatively impacting others; and

- Providing commercial vehicle drivers with timely information on how to proceed through or bypass a facility without negatively impacting others

The method for achieving these objectives at a reasonable cost for both public and private stakeholders will vary by the type of fixed facility and mobile site. The vast majority of states are actively using some form of mainline screening to evaluate commercial vehicles travelling on highways within their state.

Common functionalities used by most states at screening facilities include WIM and AVI systems that gather data related to the commercial vehicles and motor carriers from a CVIEW-based system. The most common AVI technologies currently being utilized are vehicle transponders, cellular-based applications, or some combination of LPRs and/or USDOT# readers. DMS and signalization are used to direct commercial vehicles to remain on mainline or to enter a fixed facility or pull-off area for inspection.

Data collected by the AVI is integrated with WIM data and displayed for enforcement personnel evaluation. This integrated information is typically presented using color-coding to help enforcement personnel easily identify potential violations. An effective enforcement personnel interface allows enforcement staff to quickly assess the information and determine if there is a need for any additional inspection.

Some states use an auto-calibration system to ensure mainline WIM accuracy. The auto-calibration system compares vehicle WIM data against static or portable scale data and then calibrates the WIM as necessary. A highly accurate WIM system enables enforcement personnel to focus their efforts on those vehicles most likely in violation of weight regulations and helps to minimize the volume of commercial vehicles required to exit the mainline for further inspection.

Most states require oversize and overweight permits and credentials to be acquired prior to the beginning of each trip. Credentials are obtained in many states through an online issuance system, a permit service agency, or verbal interaction with the credential-issuing agency over the phone or in person. This practice allows fixed facility and mobile enforcement personnel to focus solely on enforcement functions.

6.3.4.1 DATA COLLECTION AND INTEGRATION

Several states have found that VSFs are a major source of commercial vehicle and non-commercial vehicle data to enhance responsibilities of different state agencies. Data collected electronically at VSFs include vehicle counts, classification, size, weight, carrier credentials and safety, commercial driver safety (includes emerging required electronic log books), and commercial vehicle safety.

States use commercial vehicle counts and classification data to support size, weight, and safety enforcement, as well as traffic modeling tasks. VSF data are also used by decision makers in multiple agencies or areas to determine mobile enforcement strategies and as support for justification of enforcement staffing needs, program investments, and acquisition of improvement funds.

VSF data comes from various technology applications and other remote sources. A challenge for system integration is development of an approach to integrate data from multiple applications

and sources into a user-friendly format, preferably a single computer screen display, for multiple types of users and purposes:

- Mobile enforcement staff: for onsite, real-time mobile enforcement
- Program operations management: for monitoring performance, including trend analysis, and enforcement strategy development and implementation
- Senior agency management: for program oversight

6.3.4.2 PERFORMANCE OF WIM SENSOR TECHNOLOGIES USED IN DIFFERENT STATES

The following provides an overview of the information needed to define the requirements for a WIM application installation, regardless of the type of WIM system (i.e., bending plates, multi-load cells, quartz piezoelectric, or single load cells):

- Type of WIM system
- For existing pavement: type and thickness; base and sub-base material types and thickness; density of base and sub-base; susceptibility to water intrusion; and rutting of existing pavement
- Length of control pavement before and beyond the WIM sensor
- Presence of water control devices in any portion of the control pavement or if the control pavement is located under a bridge
- Smoothness of the control pavement designed to meet ASTM 1318-09 throughout life of WIM application
- Sealant type used (summer or winter) for control pavement construction
- Type of materials used to clean surfaces prior to sealants being applied to control pavement

To appropriately evaluate each type of WIM technology for use in a state, all of these factors must be analyzed to understand what portion of the overall WIM application is the weakest link in the system. This analysis is useful for identifying the cause of WIM application accuracy issues, as the WIM sensor itself may not be the cause of the problem. Each state has its own unique considerations in selecting the most appropriate type of WIM system to be used, including the type of pavement, base and sub-base materials, WIM installation and maintenance expertise, and volume of axle loading.

6.4 FUTURE TRENDS IN COMMERCIAL VEHICLE ENFORCEMENT

Advances in functionalities and technology could expand mainline commercial vehicle credential screening to include verification of oversize and overweight permits and hazmat information. The state of Oklahoma is one of the leading states in the testing and implementation of electronic oversize and overweight permits verification. Maine is a leader in hazmat placard reading in an E-screening environment.

Additional mainline screening capability in areas such as driver credentials, electronic logbook verification, or on-board vehicle diagnostic screening is also at the forefront. Commercial vehicle enforcement technology will continue to move towards increasing the efficiency of enforcement operations by gathering more information on commercial vehicles and commercial drivers in advance of direct enforcement areas so that only those potentially in violation of regulations are required to stop for evaluation and inspection.

Virtual enforcement, not just screening capability, is another area where improvements in technological applications will have a significant impact in the near future. Many of the weigh-related tasks currently performed at direct enforcement areas will be able to be accomplished virtually, from a remote location. Also, a few states recently have deployed and are using unmanned virtual enforcement facilities with no permanent enforcement personnel on-site. Several states are interested in this approach, as it reduces the number of enforcement personnel needed to operate the facility.

The benefit to agencies provided by these currently evolving and future technological advancements primarily will be increased commercial vehicle enforcement operations efficiency and effectiveness. These advancements will enable enforcement staff to better focus on those vehicles and drivers most likely to be in violation of regulations, with a goal of achieving improved overall motor carrier industry compliance with regulations. Additionally, efficiency benefits to agencies may include more productive use of enforcement personnel in the operation of fixed facilities, as well as mobile enforcement through use of VSFs.

Importantly, benefits to the commercial vehicle and motor carrier industries include a reduction in fuel and operating costs and improved efficiency, as a result of fewer delays for most commercial vehicles that will be able to bypass enforcement facilities, and faster processing for those vehicles requiring weighing or inspection resulting from mainline screening improvements. This serves as a form of recognition for compliance with state and federal commercial vehicle regulations and laws.

7.0 LIST OF TECHNOLOGICAL COMPONENTS AND DATA MODULES

This section of the report describes the technological components and data modules of the planned pilot VSF system. This information is suggested for use by CTDOT for the purposes of preparing an RFP to solicit proposals, as well as for contracting with the selected proposer. Also, this information provides a framework for use by proposers who will identify specific details for equipment and systems included in their proposal.

7.1 SYSTEM DESCRIPTION

The CTDOT and CTDMV Virtual Screening Facility (VSF) system shall include the gathering of business and technical requirements, design, furnishing, and installation of equipment; system integration; acceptance performance testing; and a five-year operations and maintenance (O&M) period for the full VSF system and subsystems described and reference documents defined in this chapter. The system shall be located on I-91 southbound just north of the Route 510 overpass. The selected contractor ("Contractor") shall meet the requirements specified herein.

The objective of CTDOT and CTDMV is to develop, construct, and utilize a fully operative VSF system that accurately and automatically detects commercial vehicles while in motion that are possibly in violation of federal and state laws and codes, and collects general traffic data for commercial and non-commercial vehicles.

7.2 CONTRACTING CONSIDERATIONS

The development, construction and implementation of the pilot VSF includes several tasks and activities to support system functionalities:

- Resurfacing the control pavement highway segment to meet smoothness requirements
- Selection, purchase and installation of equipment
- Integration of VSF data with information from other state and federal sources.

7.3 DESCRIPTION OF FUNCTIONALITIES

The VSF shall detect commercial vehicles that are possible violators of federal and state laws and codes traveling in the three lanes on the segment of I-91 southbound just north of the Route 510 overpass:

- Capacity: 1,200 vehicles per hour per lane.
- Screening Technologies: Quartz Piezoelectric Weigh-in-Motion (WIM) sensors, an overview camera, a License Plate Reader (LPR), inductive loops and over height detectors to cover three lanes, and a USDOT# reader in the right lane only shall be used

to detect vehicles. Output from these devices provides the VSF data collected for each commercial vehicle per lane.

- Maximum weight and axle spacing limitations shall be programmable and password protected.
- Overview, LPR and USDOT# images for vehicles exceeding the pre-programmed limitations shall be stored.
- Overview, LPR and USDOT# images with WIM data and information shall be transmitted via fiber optic communication to a designated server.
- The VSF designated server shall be located at a site to be determined by CTDOT/CTDMV in consultation with the fiber communications vendor, and as necessary with the Connecticut Department of Administrative Services, Bureau of Enterprise Systems and Technology (DAS/BEST).
- Overview, LPR and USDOT# images shall be posted on the server per CTDOT/CTDMV requirements. These images shall be available for display on laptop computers and other types of mobile devices as specified by CTDOT/CTDMV through a web-based portal without the use of proprietary equipment or software.
- A method for entry, storage, and printing of static weights from laptop computers and other types of mobile devices as specified by CTDOT/CTDMV shall be provided with functionality for corresponding vehicle static weight data to be transmitted to the VSF for WIM auto-calibration.

VSF functionality shall provide real-time continuous and efficient data gathering of commercial vehicles to identify those potentially violating federal and state codes through WIM data, overview pictures, and license plate number and USDOT# pictures with optical character recognition (OCR) data:

- Capture and posting of Overview, LPR and USDOT# images on the designated server 24 hours a day and 7 days a week. Daytime images shall be color and nighttime images shall be black and white.
- Commercial vehicles shall be divided into potential violators and non-violators based upon programmable and configurable criteria/thresholds set by an authorized user.
 - o Potential violators are commercial vehicles that may be in violation of any of the following:
 - ◆ Connecticut weight requirements
 - ◆ Posted speed limit
 - ◆ Off the WIM (*Commercial vehicles that do not pass over the WIM correctly*)
 - ◆ Over dimension axle length and/or axle internal bridge, and over height
 - ◆ Safety score and credentials check through Connecticut CVIEW, MCMIS, and other data
 - o Non-violators are commercial vehicles not violating any of the preceding

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The VSF equipment used to screen vehicles at the site is shown in Table 7.0

TABLE 7.0. VSF EQUIPMENT FOR SCREENING VEHICLES)

Equipment	Usage and Notes
Quartz Piezoelectric WIM sensors	(2) per lane; three lanes
Loops for vehicle presence detection to activate WIM sensors and cameras	(2) per lane; three lanes (Note: (If the integrator prefers, it is acceptable to activate WIM sensors and cameras with only one loop)
Overview camera	(1) per lane; three lanes
LPR camera	(1) per lane; three lanes
USDOT# reader	(1) for right lane only (Note: pole mounted with VSF cabinet)
Over Height devices	(2) – (1) for right lane; (1) for middle and left lanes
Pole-mounted VSF cabinet for the controller and processors	(1) for VSF site

In summary, this complete VSF system includes, but is not limited to, the following components and accessories:

- Quartz Piezoelectric WIM sensors
- Vehicle presence detectors – inductive loops
- Overview, LPR and USDOT# cameras
- Over Height devices
- Illuminators for cameras
- Software for:
 - o VSF at the roadside
 - o Camera controls at the roadside
 - o Computer for processing VSF roadside data
 - o Reports to be determined as defined by CTDOT and CTDMV
 - o Multilevel password protected web interface for access to VSF data and reports
 (Note: CTDOT/CTDMV will need to define levels of password controls for daily operations, supervisors, management, and maintenance staff, etc.)
- Data needs to be provided in a non-proprietary format for use and integration with source systems, such as CVIEW, CAD/RMS (Computer-Aided Dispatch and Records Management System)

7.4 REFERENCES: APPLICABLE STANDARDS

- CTDOT Standard Specification for Road and Bridge Construction
- CTDOT Design Standards
- CTDOT Standard Drawings

- CTDOT Statewide Scale Maintenance Agreement (*Current Agreement: Full Preventive Maintenance and Service of Truck Weighing Scales for DOT at Various Locations; Contract 08PSC0183; Term: 2008 -2013 with option for extensions not to exceed length of original term*)
- International Electrotechnical Commission Standards (IEC)
 - o IP68 – Ingress Protection Rating
 - o IP65 – Ingress Protection Rating
 - o IP54 – Ingress Protection Rating
- National Fire Protection Association (NFPA):
 - o 70 - National Electric Code (NEC)
- National Electrical Contractors Association (NECA)
- American Society of Testing and Materials (ASTM):
 - o E1318 - 09 - Standard Specification for Highway WIM Systems with User Requirements and Test Methods.
- National Institute of Standards and Technology (NIST): Handbook 44
- National Electrical Manufacturers Association (NEMA)
- Society for Protective Coating (SSPC) Surface Preparation Specifications
 - o SP 1- Solvent Cleaning: Removal of oil, grease, soil, drawing and cutting compounds, and other soluble contaminants
 - o SP 6 - Commercial Blast Cleaning
 - o SP 10 - Near-White Blast Cleaning

7.5 MATERIALS: FUNCTIONAL REQUIREMENTS

- A. The Contractor shall collect license plate-based, USDOT# and Overview image data using cameras that the Contractor shall procure; install; test; and operate and maintain. The Contractor shall provide materials needed to supplement utility power, and shall provide equipment necessary to operate the system and transmit data to and from the designated server for analysis and processing of VSF data.
- B. The Contractor's camera subsystem technologies shall not be intrusive to the pavement, except for inductive loops used to trigger the cameras that can be the same loops used to activate the WIM sensors.
- C. The Contractor shall provide data that has been encrypted and compressed from the VSF via a standardized interface. The Contractor shall work with CTDOT/CTDMV to determine the exact nature of the standardized interface(s) and the format for data. As part of this process, the Contractor shall document the interfaces necessary to support this project including existing interfaces.

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- D. The Contractor shall provide the capability for CTDOT/CTDMV technicians to troubleshoot the system at the VSF site, as well as remotely, using computer-based system.
- E. The Contractor shall provide software to CTDOT/CTDMV necessary to perform maintenance and configuration activities.
- F. The Contractor's VSF system shall be capable of collecting and storing data 24 hours per day, 7 days per week, and 365 days per year in three lanes. VSF system data and reporting, including customizable reports from integration of data with other source systems, shall be provided to CTDOT/CTDMV.
- G. The Contractor's VSF system shall be capable of collecting, storing, and transmitting license plate and USDOT# data, and Overview images for configurable periods.
- H. The data provided to CTDOT/CTDMV shall include the following attributes:
 - 1. Encrypted and compressed license plate identification.
 - 2. A timestamp for when each license plate alphanumeric and USDOT# information was collected.
 - 3. Identification of the data collection station.
 - 4. Confidence value of each license plate read.
- I. The Contractor shall ensure that for qualifying license plates¹⁸ that fully pass within the LPR field of view:
 - 1. the vehicle penetration rate, which is defined as the number of license plates accurately captured divided by the total number of vehicles passing an LPR, shall be a minimum of 85%;
 - 2. at least 85% of license plates captured shall have a confidence level that is greater than or equal to 90%;
 - 3. no more than 10% shall have a confidence level between 70% and 90%;
 - 4. no more than 5% shall have a confidence level that is less than 70%;
 - 5. system software shall have the capability for enforcement staff to enter license plate alphanumeric and jurisdiction and conduct database searches through the designated server. The Contractor will deliver software program documentation to CTDOT/CTDMV. If any revisions are made to the system software during construction, the revised final version of the software program documentation shall be delivered to CTDOT/CTDMV for approval before the Acceptance Performance Test.
- J. The Contractor shall ensure that for qualifying USDOT#s that fully pass within the USDOT# field of view:
 - 1. the vehicle penetration rate, which is defined as the number of USDOT#s accurately captured divided by the total number of vehicles passing a USDOT#

¹⁸ Qualifying license plates shall be characterized as being of current plates in the mainland 48 states, Canadian Provinces and Mexican States issued, legally mounted, unobstructed, and undamaged.

camera, shall be a minimum of 80%;

2. at least 80% of USDOT#s captured shall have a confidence level that is greater than or equal to 90%;
 3. no more than 10% shall have a confidence level between 70% and 90%; and
 4. no more than 5% shall have a confidence level that is less than 70%.
- K. The system shall provide information concerning the system's health, including but not limited to, information on the VSF, power supplies, and communications.

7.6 QUARTZ PIEZOELECTRIC WEIGH-IN-MOTION SENSORS

A. Quartz Piezoelectric WIM sensors:

1. Sense the weight of each wheel group of the commercial vehicle as it moves in motion over the sensors.
2. Determine vehicle speed and axle spacing without the need of other in-road devices.
3. Sense, with the system software, any wheel group that fail to go fully over the sensors.
4. Provide two WIM sensors per vehicle path.
 - a. (1) two-meter sensor for right wheel group path
 - b. (1) two-meter sensor for left wheel group path
5. WIM accuracy on vehicles loaded above 60,000 pounds and traveling between 5 and 85 miles per hour shall be as follows as per ASTM E1318-09 Type III WIM System:
 - a. Axle weights $\pm 20\%$ (95% of commercial vehicles)
 - b. Tandem weights $\pm 15\%$ (95% of commercial vehicles)
 - c. Gross weights $\pm 10\%$ (95% of commercial vehicles)
 - d. Axle spacing ± 6 inches or 5% (68% of axles), whichever is greater

B. Sensors

1. Degree of ingress protection from solids and liquids (IP68).
2. Provide lightning and surge protection from the CTDOT Qualified Products List.

7.7 POLE MOUNTED VSF CABINET

- A. Communication capability with the Quartz Piezoelectric sensors, vehicle presence detectors, and cameras.
- B. Mounted on USDOT# camera pole.
- C. Capability to support an interface for Automated Vehicle Identification (AVI) equipment.
- D. Receive cables from the Quartz Piezoelectric sensors, vehicle presence detectors, and cameras.
- E. Include a module for terminating in-road and roadside items (Quartz Piezoelectric sensors, vehicle presence detectors and cameras) and provide necessary communication to the designated server.
- F. Shall include power supply, convenience duplex outlet with light, and lightning/electric surge protection, and a UPS to operate the VSF for one hour.
- G. The VSF cabinet shall be equipped with an approved heating/cooling device capable of maintaining an internal temperature that meets the operating requirements of equipment provided by the Contractor.
- H. Capability to sample outputs from the Quartz Piezoelectric sensors and vehicle presence detectors, over the full range of operating speeds and accurately determine the axle weights and axle spacing.
- I. Provide ground buss for cables and lightning protection equipment.
- J. Provide unique key for door locking mechanism (not a standard traffic cabinet key). Coordinate with CTDOT/CTDMV for details.

7.8 VSF COMPUTER

- A. The VSF computer specification and performance requirements shall be determined by CTDOT/CTDMV in consultation with the Contractor. The computer shall be designed for optimal performance based on system functionalities with a web-based interface for remote diagnostics.
- B. The minimum acceptable configuration shall include:
 - 1. Conform to CTDOT/CTDMV and DAS/BEST current information security computer standards, including data encryption and personal identifiable information (PII) security, and VSF computer to designated server firewall protection.
 - 2. System utilities and diagnostic software.
 - 3. Interface to the VSF cabinet.
 - 4. Interface to digital outputs.
 - 5. Surge protection shall be from CTDOT qualified products list.
 - 6. System multilevel password protected lock for access restriction for different users.

7. Access ports, cables and accessories to provide a working VSF system.
8. Diagnostic software to analyze the condition of the vehicle weighing process:
 - a. Vehicle presence detectors operations.
 - b. Sensors signal.
 - c. The VSF system integrator shall provide software necessary for complete and efficient operation of the WIM and camera systems. The software must be supplied with the report formats. Report formats must be supplied as an integral part of the VSF system. The software must allow the user Virtual Network Connection (VNC)/or Remote Desktop Connection and Virtual Private Network (VPN) access to perform diagnostics.
9. Transmittal of pictures with WIM data to the designated server
10. Capability to set overweight limits and determine which pictures should be transmitted to the designated server.
11. Capacity for storage backup of WIM and pictures on VSF computer is an option to be determined by CTDOT/CTDMV.
12. Remote diagnostics and software updates.

7.9 CONTROLLER, AND OVERVIEW, LPR AND USDOT# CAMERA SUBSYSTEMS

- A. The intent of this section is to ensure the VSF controller is designed and constructed according to the following specifications:
 1. Constructed in a standard outdoor pole mounted cabinet
 2. Communication to the outdoor pole mounted VSF cabinet shall be defined and provide access to transmit pictures to the VSF computer/controller
 3. Camera processors shall be located within the cameras, not in the VSF controller
- B. Remote Monitoring
 1. Enforcement staff shall have the capability to choose the vehicle and violation records to be viewed based on the set of display settings (Figure 7.0: Example of Display Settings):
 - a. VSF WIM location.
 - b. Number of vehicles to display at one time on vehicle overview page.
 - c. Overview display filter – display vehicles, display bypass violators only, display weight violators only, display violators, weights, speed, overdue citations, off WIM, repeat commercial vehicle tags per week and per month.
 - d. Refresh time for overview screen in user definable range of 5-10 seconds.

Virtual WIM Remote Monitoring Website METTLER TOLEDO

< Go back to overview screen **Display Settings** System Time: 12/4/2006 8:52:55 AM

Display Settings

Configure your browser display by setting your display preferences below, then click the OK button to save them.

Virtual WIM Location Punta Gorda

Number of Vehicles to Display on Overview 20

Overview Display Filter

- Display All Vehicles
- Display Bypass Violators Only
- Display Weight Violators Only
- Display All Violators

Refresh Time for Overview Screen (in seconds, min. 30) 120

OK Cancel

FIGURE 7.0. EXAMPLE OF DISPLAY SETTINGS
(SOURCE: FLORIDA DOT, TECHNICAL SPECIAL PROVISIONS)

2. After choosing the display settings, the vehicle overview screen (Figure 7.1: Example of Vehicle Overview) shall show the following information.
 - a. Overview commercial vehicle picture.
 - b. Direction of travel – Northbound, Southbound, Eastbound or Westbound.
 - c. Potential violations in the following categories:
 - i. Gross weight by classification
 - ii. Axle weight
 - iii. Tandem weight
 - iv. Tri-Tandem weight
 - v. Speed
 - vi. Hot List (as defined by CTDOT/CTDMV)
 - vii. PRISM
 - viii. Imbalance from side to side
 - ix. Axle dimensions
 - x. Internal and external bridge
 - xi. Rear bridge (king pin for non-interstate locations)
 - d. Date (MM/DD/YY) and Time (HH: MM: SS)
 - e. License plate alphanumeric with OCR (LPR)
 - f. USDOT# with OCR (USDOT# reader)

INNOVATIVE TECHNOLOGY DEPLOYMENT: DEVELOPMENT OF A VIRTUAL SCREENING FACILITY PILOT PROJECT FOR CT'S COMMERCIAL VEHICLE ENFORCEMENT PROGRAM
 LIST OF TECHNOLOGICAL COMPONENTS AND DATA MODULES

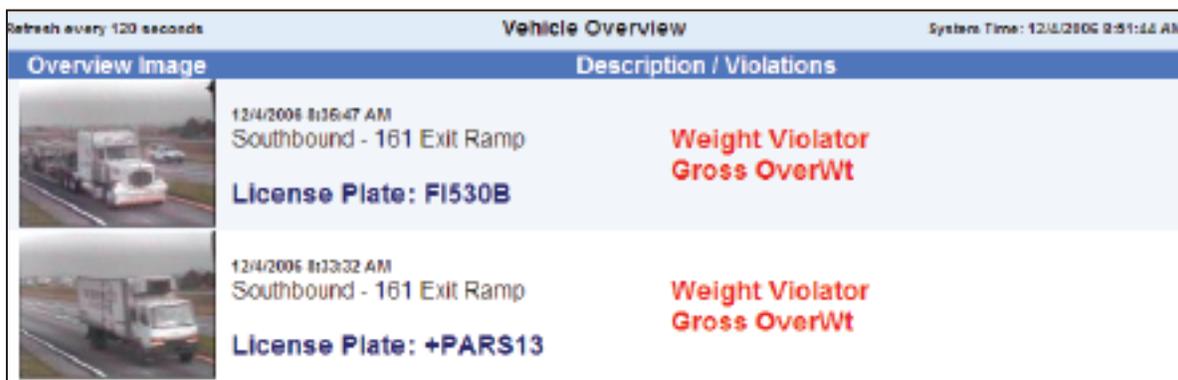


FIGURE 7.1. EXAMPLE OF VEHICLE OVERVIEW
 (SOURCE: FLORIDA DOT, TECHNICAL SPECIAL PROVISIONS)

The screen shall automatically update showing new vehicles that exceed the preset limits. The screen shall automatically refresh (maximum of 10 seconds) per the time display setting and/or manual refresh functions.

- From the vehicle overview screen, enforcement staff can click on a vehicle record to see the vehicle detail screen (Figure 7.2: Example of Vehicle Details). This shall show a larger picture and detailed information such as vehicle class, speed, gross weight, axle spacing, bridge weights, and licence plate and USDOT# images.

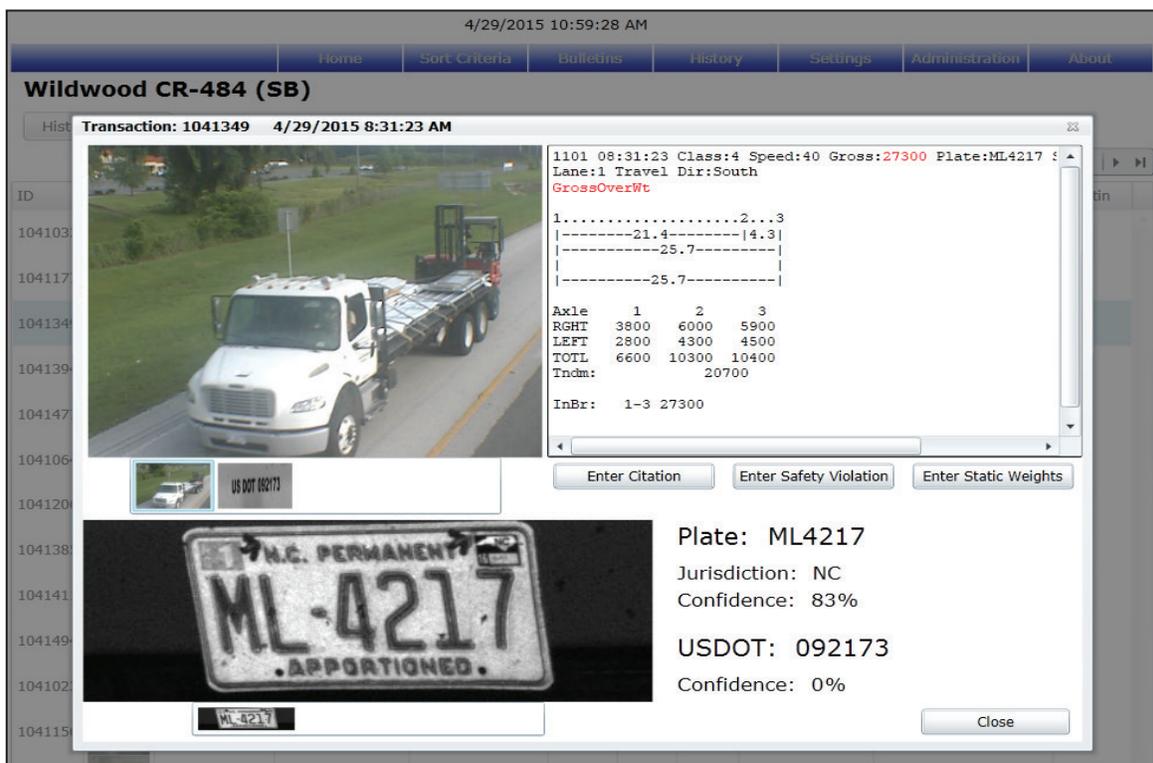


FIGURE 7.2. EXAMPLE OF VEHICLE DETAILS
 (SOURCE: FLORIDA DOT, TECHNICAL SPECIAL PROVISIONS)

C. Lightning Protection

1. A comprehensive lightning protection system shall be provided with the VSF system and covered by warranty. This system shall be tested and modified to achieve no greater than a maximum of 10 OHM at the grounding point.
2. The VSF system including WIM sensors, controller, computer, illuminators and cameras shall be covered by the lightning protection system.

D. Minimum Overview Camera, LPR Camera, and USDOT# Reader Camera Specifications

1. Overview Camera

- a. Type of image data collected shall be color digital (primary) and monochrome image data during the dark/night time (secondary). The camera shall have capability to switch automatically between these image types.
- b. Resolution: Phase Alternating Lines (PAL) 625 lines
- c. Power: 120 volts at 60 Hz
- d. Operating Temperature: -40°F to 158°F
- e. Operating Humidity: 10%~90% (non-condensing)
- f. Ingress Protection Rating: IP65
- g. Processor: Internal
- h. Triggered by external sensor

2. LPR Camera

- a. Type of image data collected shall be color digital (primary) and black/white analog (secondary).
- b. One illuminator with infrared output per camera shall supplement dark/night time operations of this subsystem.
- c. The camera/optical character recognition shall capture commercial vehicles operating at up to 120 mph at a minimum of 85% of the alphanumeric and jurisdiction on commercial vehicle license plates in daylight and night darkness. When the environment is no longer conducive to maintain the 85% confidence level in color digital, the system shall automatically switch to black/white analog.
- d. Resolution: 5 mega pixel (minimum)
- e. Power: 120 volts at 60 Hz
- f. Operating Temperature: -40°F to 158°F
- g. Operating Humidity: 10%~90% (non-condensing)
- h. Ingress Protection Rating: IP54
- i. Processor: Internal
- j. Triggered by external sensor

3. USDOT# Camera

- a. Type of image data collected shall be shall be color digital (primary) and black/white analog (secondary).
- b. One illuminator with infrared output per camera shall supplement dark/night time operations of this subsystem.
- c. The camera/optical character recognition shall capture commercial vehicles operating up to 75 mph at a minimum of 80% of the alphanumeric USDOT# on commercial vehicles in daylight and night darkness. When the environment is no longer conducive to maintain the 80% confidence level in color digital, the system shall automatically switch to black/white.
- d. Resolution: 5 megapixels
- e. Power: 120 volts at 60 Hz
- f. Operating Temperature: -40°F to 158°F
- g. Operating Humidity: 10%~90% (non-condensing)
- h. Ingress Protection Rating: IP54
- i. Processor: Internal
- j. Triggered by external sensor

7.10 FIXED BI-DIRECTIONAL COMMUNICATION SUBSYSTEM

Dielectric Fiber Optic Cable (12 strands) Outside Plant (OSP) type by Corning

- A. Single-mode optical fiber (SMF)
- B. Core/Cladding = 8-9/125 microns
- C. Attenuation @ 1,310/1,550 nm = 0.4/0.25 dB/km
- D. Bandwidth = approximately 100 Terahertz
- E. Tensile load strength for installation = 600 lbs. minimum

7.11 METHODS OF CONSTRUCTION

7.11.1 *Installation Plan*

The Contractor shall develop and adhere to an installation plan that has been signed, sealed, and certified by a Professional Engineer registered in the State of Connecticut. The installation plan shall provide a detailed, structured set of installation tasks and schedule to be performed by the Contractor. The installation plan shall be approved by CTDOT prior to installation.

7.11.2 *Performance Monitoring and Quality Assurance Plan*

- A. The Contractor shall develop and implement a performance monitoring and quality assurance plan.

- B. This plan shall document the Contractor's compliance with the functional requirements listed in this document.
- C. As part of the performance monitoring and quality assurance plan, the Contractor shall generate a performance statistics report for inclusion in a monthly status report that will commence after system acceptance. The contents of the performance statistics report shall indicate whether the Contractor is meeting the functional requirements related to each of the project's program areas:
 - 1. Accuracy of weighing axles, axle groups, internal and external bridges.
 - 2. Accuracy of measuring lengths between axles and overall wheelbase.
 - 3. Accuracy of images matching commercial vehicle data.
 - 4. Accuracy of OCR output matching the license plate number and USDOT#.
 - 5. Accuracy of WIM data matches for commercial vehicles.
- D. The Contractor shall make system improvements as indicated by the results of its performance monitoring activities.
- E. The performance monitoring and quality assurance plan shall be submitted to CTDOT for approval prior to implementation.

7.11.3 Operations and Maintenance Plan

The Operation and Maintenance (O&M) plan shall include a preventive maintenance checklist and schedules for recommended servicing of the complete system for CTDOT/CTDMV approval. If any manufacturer does not provide an appropriate O&M checklist and schedule, the Contractor shall provide a checklist and schedule for each and every processing item. The following is an abbreviated list and not limited to items to be included on the O&M checklist and schedules:

- A. VSF Computer/Processor
- B. Controller
- C. WIM Sensor
- D. Vehicle presence detection
- E. Overview camera and strobe
- F. LPR camera and strobe
- G. USDOT# camera and strobe
- H. Over Height device
- I. VSF cabinet HVAC
- J. VSF cabinet air filters
- K. Designated server, as appropriate

7.11.4 Staffing Certification

At the pre-construction meeting, provide certifications for each staff person responsible for installation and O&M for CTDOT approval.

7.12 TRAINING PLAN

- A. The Contractor shall develop a training plan for training CTDOT, CTDMV and CSP staff in the operations and maintenance of the VSF system. The training shall consist of one day of classroom training and one day of hands-on training for each group and be video and audio recorded. The groups include
 - 1. CTDMV and CSP enforcement and trainer staff;
 - 2. CTDOT planning and trainer staff; and
 - 3. CTDMV/CTDOT maintenance and trainer staff.
- B. Ensure that the training course provided pertains specifically to the individual groups, presuming that the course participants have no prior knowledge of the system or the associated technology. The training shall be customized to the intended audience or user group - enforcement, planning and maintenance personnel.
- C. Provide this training through the use of lectures, field demonstrations, hands-on workshops, and similar instructional methods. At least 30 days before the training is to begin, submit the following information to CTDOT/CTDMV for approval:
 - 1. Course outline covering training duration, equipment, facility required, and maximum number of participants per training session for effective instruction.
 - 2. One complete set of the training materials proposed for use, including the product operations manual.
 - 3. Qualifications of the proposed installers, instructors, calibrators and O&M personnel for CTDOT/CTDMV within one week of notice to proceed.
- D. CTDOT/CTDMV will review and approve the training materials and class schedules, or request changes.
- E. Conduct training courses at no additional cost to CTDOT at CTDOT, CTDMV, and/or CSP provided locations on dates and at times to be determined.
- F. Ensure that the training materials for each course include detailed software documentation, manuals, presentations, visuals, diagrams, and other handouts for each trainee. These materials should be planned to be used by trainees as subject guidance, as well as quick-reference material tools for future use.
- G. Allow a maximum class size of no more than 12 trainees per class.
- H. Deliver approved course materials to CTDOT/CTDMV in a reproducible, electronic format, and if requested a hard copy for each department two weeks before the course starts.

- I. Provide training and training materials.
 - 1. Contractor shall provide 16 hours of technical training to certify maintenance staff in the following:
 - a. One 8-hour day for the maintenance of Class 1 Piezoelectric sensor and the controller.
 - b. One 8-hour day for the maintenance of cameras (Overview, LPR and USDOT#).
 - 2. CTDMV/CSP enforcement staff shall receive 16 hours of training.
 - a. One 8-hour day of in-class training
 - b. One 8-hour day of field training
 - 3. CTDOT planning and traffic management staff shall receive 16 hours of training.
 - a. One 8-hour day of in class training
 - b. One 8-hour day of field training
- J. List of preventative maintenance needed on the entire VSF system.
- K. Provide schedule for the list of any preventative maintenance.

7.13 WARRANTY

The warranty shall include standard general terms and conditions as required by CTDOT/CTDMV and DAS/BEST, as well as specific terms related to the installation, operation, and repair of the VSF, including but not limited to installed equipment, software and systems, as follows:

- A. Contractor shall warrant the VSF system's equipment in writing against defective material, lightning, and workmanship, including preventive maintenance which shall consist of: recalibration, cleaning of lenses with water and non-abrasive towels, cleaning illumination lenses, adjust cameras and strobes, clean reflector (air filter - replace once annually), and bulb.
- B. Contractor shall warrant the VSF system to perform as required in accordance with the VSF technical provisions, giving proper and continuous service under conditions required and specified.
- C. Contractor's full warranty, including preventive maintenance, shall be for a period of five years, but not less than each manufacturer's standard warranty for the products from the date of final acceptance of the project.
- D. The Contractor shall furnish the written warranty to CTDOT at the time equipment performance supporting data is submitted.
- E. The warranties shall state that they are subject to transfer to the CTDOT.
- F. The Contractor's written warranty must be acceptable and approved by CTDOT/CTDMV 45 calendar days prior to the anticipated installation of the warranty's subject.

- G. The Contractor shall also warrant during construction and until final acceptance the VSF system equipment furnished and installed as described in the Contractor's contract for services.
- H. The warranty shall be in accordance with the VSF technical provision and suitable to CTDOT/CTDMV for the purpose intended.
- I. VSF system shall function in the manner intended by the CTDOT/CTDMV and be acceptable to CTDOT/CTDMV.
- J. The warranty shall cover materials, equipment, service, labor; travel expenses, and incidentals necessary for warranty service.
- K. The VSF system warranty shall exclude damage caused by flooding, accidents, vandalism, or natural disasters.
- L. Equipment and software provided by the Contractor as part of this project shall be warranted and guaranteed against defects and/or failures in design, materials, and workmanship from the date of final system acceptance as recorded by CTDOT.
- M. The warranty shall provide that, in the event of a malfunction during the warranty period, the defective system component shall be replaced with a new component. The Contractor shall be responsible for labor, travel, equipment and shipping costs for installing the new component.
- N. A log shall be maintained for warranty and preventive maintenance related operations conducted after final acceptance throughout the warranty period. Any replacement parts, repair hours, and a brief description of activities shall be reported in the log and submitted to CTDOT for each occurrence.
- O. No additional charges shall be incurred by CTDOT during the warranty period.

7.14 PROJECT INVENTORY

- A. The Contractor shall keep an inventory of equipment purchased with CTDOT/CTDMV or federal funds for use on this project. Equipment information to be included as part of this inventory shall include a minimum of the following:
 - 1. A description of equipment
 - 2. Serial numbers
 - 3. A CTDOT property decal
 - 4. Date of purchase
 - 5. Location of equipment with the latitude/longitude coordinates and the mile post/offset distance from the roadway
 - 6. Warranty information, including expiration date
 - 7. Contractor contact information
- B. The Contractor shall also provide CTDOT a legal copy of project software and detailed documentation.

7.15 SUBMITTALS

- A. Submit as specified in CTDOT's Standard Specifications for Road and Bridge Construction the following, including but not limited to:
1. Equipment drawings
 2. General arrangements
 3. Foundation requirements
 4. Circuit diagrams
 5. Field wiring diagrams
 6. Instruction manuals
 7. Bill of materials
 8. Spare parts list
 9. Samples
 10. Contractor's product data
 11. Certified test reports
 12. Material certifications
- B. In addition to the items specified in CTDOT Standard Specifications for Road and Bridge Construction, the Contractor shall submit the following equipment documentation for acceptance prior to fabrication:
1. Detailed description of how the VSF system requirements are met, including a step-by-step description of how the VSF system would function in processing each of the following violations, as well as the non-violation scenario:
 - a. Overweight
 - b. Imbalanced from side to side
 - c. Over-speed
 - d. Over-length
 - e. Change in speed between first axle and last axle
 - f. Over height
 2. Vehicle presence detection, according to the contract documents.
- C. Contractor shall submit six complete sets of full size drawings to CTDOT:
1. Drawings shall include field wiring, conduits, pull boxes, transformers, and other pertinent data required to make a complete installation. Pull boxes, VSF pole and electrical service as-built locations shall be documented using latitude and longitude associated with a U.S. Geological Survey grid system or datum.
 2. Drawings are to be approved by CTDOT prior to fabrication.

3. Directional Bore As-Built Plans shall be provided in accordance with the CTDOT Road and Bridge Specifications.
4. After approval, one complete set of reproducible drawings certified for construction in format specified by CTDOT shall be submitted.

D. The Contractor shall

1. Design foundation supports.
2. Submit shop drawings, along with the supporting calculations, to CTDOT for approval.
3. Provide as-built drawings that show type and location of conduits, pull boxes, junction boxes, vehicle presence detection devices, WIM strips, poles, cameras and any other items installed in the right-of-way.
4. Provide technical documentation on accessories used in the system.

7.16 INTERFACE CONTROL DOCUMENTS

- A. The Contractor shall install the system devices detailed in the design plans and specifications.
- B. Device installations shall not occur until CTDOT has reviewed and approved the Contractor's installation plan.
- C. Project-related shop drawings submitted by the Contractor shall be endorsed (i.e. signed, sealed and certified) by a Professional Engineer licensed in the State of Connecticut.
- D. The Contractor shall consider the following information when developing shop drawings:
 1. Maximize the use of the utility power
 2. Effectiveness of VSF system
 3. Maximize accessibility and ease of equipment maintenance
 4. Maximize the safety of equipment maintenance personnel and the traveling public
 5. Minimize the impact to concurrent/future construction projects
 6. Minimize utility conflicts and adjustments
 7. Minimize traffic impact during installation and O&M
 8. Minimize environmental impacts
 9. Minimize aesthetic and visual impacts
 10. Ensure full compliance with CTDOT mounting requirements
- E. The Contractor shall submit six sets of shop drawings for each of the submittals identified herein. Each submittal shall consist of both electronic PDF format on CDs and hard copies.

7.17 FIELD DEVICE INSTALLATION

- A. VSF equipment shall be furnished and installed in accordance with the manufacturer's recommendations and the project requirements, project documentation, and plans prepared by the Contractor and approved by CTDOT. The Contractor shall inspect equipment before installation to ensure that it is free of any defects or damage.
- B. Equipment shall be mounted on properly prepared surfaces that are adequate for the size and weight of the equipment. Power equipment, cabling, and grounding shall be installed according to the manufacturer's recommended installation procedures.
- C. The VSF system shall be installed in strict conformance with: (1) the requirement that the Contractor provides a complete and fully operable system; and (2) CTDOT standards and requirements, including Maintenance of Traffic requirements.
- D. The first order of work shall be to test and document the pavement smoothness for the WIM control pavement area 1,000 feet upstream to 100 feet downstream of centerline of the WIM strip location. This testing shall be performed before in-pavement items have been installed, and witnessed by CTDOT. The results of this test will be the foundation for assessing the accuracy of the WIM system at this location. Six sets of the Pavement Smoothness Report shall be provided to CTDOT.
- E. WIM sensor cables and wires, vehicle presence detectors, cameras and other system and subsystem items shall terminate in the pole mounted VSF cabinet.
- F. Two test commercial vehicles as per ASTM E 1318-09 shall be provided for accuracy testing of type III WIM systems and speed of data from detection devices to laptop computers in patrol vehicles.
- G. 10 random commercial vehicles of multiple classification types that are out of the general population shall be used to test the accuracy of the system.

7.18 VSF DATA AND PERFORMANCE MEASURES

During this study, CTDOT and CTDMV developed performance measures to be used to evaluate the effectiveness of the VSF and commercial vehicle enforcement operations at this site. The following data, information, and measures, as shown in Table 7.1, are presented for use by the Contractor as a template for the design of reports to be used by CTDOT and CTDMV for analysis.

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TABLE 7.1. VSF DATA AND PERFORMANCE MEASURES

VSF DATA COLLECTION	
BASELINE 0–6 Months After Installation Monitor (No Enforcement)	INITIAL ENFORCEMENT PERIOD 6–12 Months After Installation Begin Enforcement Activities
Note: Data collection should be by lane with analysis by lane and totals.	
# of vehicles classified	# of vehicles classified
% of classified vehicles weighed	% of classified vehicles weighed
# of overweight vehicles date/time	# of overweight vehicles date/time
% of classified vehicle registrations read (LPR)	% of classified vehicle registrations read (LPR)
% of LPR accurate reads	% of LPR accurate reads
# and type of registration issues (expired, suspended, stolen, etc.)	# and type of registration issues (expired, suspended, stolen, etc.)
% of classified vehicles read by USDOT# Reader	% of classified vehicles read by USDOT# Reader
% USDOT# accurate reads	% USDOT# accurate reads
# of federal OOS carriers identified (times/dates)	# of federal OOS carriers identified (times/dates)
% of time system is (on-line)	% of time system is (on-line)
Total Accuracy Rate	Total Accuracy Rate
# of OS/OW Permits	# of OS/OW Permits
PERFORMANCE MEASURES (12+ MONTHS AFTER START OF ENFORCEMENT AND ONGOING)	
1. % change in vehicles overweight (GVW) from Baseline	
2. % change in registration issues	
3. % change in OOS carriers	
4. % of overweight vehicles that have OS/OW Permits	

7.19 CONSIDERATIONS FOR CONTRACTING FOR CONSTRUCTION AND MAINTENANCE

The following provides information for CTDOT and CTDMV to guide decisions regarding agency responsibilities and tasks identified, among others, for contracting for VSF construction and maintenance.

- A. Responsibility for (*project management, funding and reporting*) for installation, maintenance, repairs, future replacement of the control pavement, WIM, cameras, strobes, loops, signage and the balance of VSF system over time.
 1. Who will contract with the VSF maintenance contractor? (*Note: Each department's standards for accuracy and quality of data will need to be considered.*)
 2. Who will be responsible for maintaining quality of pavement smoothness: CTDOT or the VSF maintenance contractor?

B. Acceptance Performance Test

1. Identify the preferred duration of the VSF Acceptance Performance Test: 30- 60- 90 days, etc. (*Note: Section 7.20.4 shows a 60-calendar day APT period*)
2. Identify the consequences/penalties for failing to meet the requirements of the APT (*Bond called/\$\$\$ penalty/returned payments/removal of system by the Contractor at their cost, etc.*)

C. System Requirements and Standards

1. Responsibility for establishing and modifying system requirements and standards as needed
2. Responsibility for ensuring that the requirements and standards are being met/achieved and identifying the information/data needed to oversee and ensure the requirements and standards are being met

D. System Integration

1. Responsibility for managing integration of systems to ensure needs are met, including hardware, software, and reporting
2. Responsibility for planning for continuous improvement by upgrading the use and integration of new/proven technologies and functionalities (*hardware/software/reporting*)

7.20 SYSTEM BURN-IN AND TESTING

7.20.1 Burn-in and Acceptance Performance Test

- A. The APT shall include a description of the Contractor's approach to verifying that the VSF integrated system meets specified requirements. The plan shall include a description of test cases that demonstrate the functional threads through the VSF system.
- B. After CTDOT/CTDMV approval of the APT, the Contractor shall develop acceptance test procedures in accordance with the approved plan. The test procedures shall
 1. be of sufficient detail that a person unfamiliar with the VSF system can execute the test procedures with a repeatable result;
 2. identify the requirements being verified in each step and describe the test set up;
 3. support the hardware and software needed for each test case;
 4. predict the result of each step in the procedure;
 5. verify the system's ability to meet or exceed VSF system requirements;
 6. include testing the VSF system functions using the communication system specified for the project by the Contractor; and
 7. commence only after CTDOT/CTDMV have approved the APT.

- C. Prior to formal acceptance testing, a test readiness review shall be held no earlier than three business days prior to formal testing. The final test procedures shall be approved by CTDOT/CTDMV. CTDOT/CTDMV and the Contractor, prior to the start of formal testing, shall sign the acceptance test procedures document.
- D. At a minimum, the test procedures shall include
1. a traceability matrix to ensure that contractual requirements that are being met by the system will be tested;
 2. test responsibilities;
 3. test monitoring methods;
 4. pretest activities;
 5. test environment requirements, including any hardware and software required for testing;
 6. a description of the expected operational outputs and test results through a traceability matrix;
 7. test duration and a proposed test schedule;
 8. a data form to be used to record data and quantitative results obtained during the test;
 9. a description of any special equipment, setup, manpower, or conditions required for the test;
 10. wherever practicable, a description of the thresholds that would qualify test results as acceptable/unacceptable;
 11. an end-to-end test plan that provides for the testing of deployed elements; and
 12. a 60-calendar day APT of deployed elements that will be initiated after the successful completion of the 14-calendar day system Burn-in.
- E. At a minimum, the system Burn-in shall demonstrate full monitoring and control of the VSF system by the Contractor via the communication system and web-based interface developed as part of the project. The Burn-in shall also verify the system's ability to provide the data collected by the VSF system deployed in the field to the designated server.
- F. As part of the APT, the Contractor shall provide a methodology for assessing the degree to which the deployed system conforms to the specified VSF penetration rate and confidence level requirements. The Contractor shall provide equipment and software necessary to carry out penetration rate and confidence level requirements testing described in this methodology.

7.20.2 Burn-in: Contractor Testing for 14-Calendar Day

- A. After equipment has been installed in accordance with the applicable requirements and plans, and each subsystem has been tested by the Contractor and is reported to

be operating properly, the 14-calendar day system Burn-in shall be conducted by the Contractor to validate the operational characteristics of the VSF system. During the Burn-in period, the Contractor shall provide qualified personnel to diagnose and repair system equipment, as necessary.

- B. In the event of a failure during the Burn-in test, each problem shall be corrected. The Contractor shall be responsible for repairing and replacing VSF system hardware and software that has become defective during the Burn-in test. Repairs made shall conform to the plans submitted by the Contractor as part of the project design and construction process. The Contractor shall be responsible for costs associated with the maintenance, repair, or replacement of equipment.

7.20.3 Hot Wash-up

A hot wash-up denotes an immediate review of a process or test to

- verify that contractor and CTDOT/CTDMV perceived the same results; or
- identify significant differences of opinion on the results of the process or test.

Immediately after the burn-in period, CTDOT/CTDMV will convene a meeting with the Contractor to discuss the results of the testing and agree on a preliminary list of actions that may result from the final acceptance test. CTDOT will provide minutes of the hot wash-up, and the Contractor shall review and comment.

7.20.4 Acceptance Performance Test for 60-Calendar Day (Contract time shall be suspended during APT)

- A. After successful completion of the 14-calendar day system Burn-in, as approved by CTDOT/CTDMV, the Contractor shall provide to CTDOT/CTDMV final software, source code and documentation of entire operating system for CTDOT/CTDMV approval. CTDOT/CTDMV shall then conduct a 60-calendar day APT. During the APT the contractor and sub-contractors shall not have direct or remote access to the site. CTDOT/CTDMV specific software and source code will be the property of and for the sole use by CTDOT/CTDMV.
- B. The system acceptance test shall test the system's ability to perform system functions in actual operating conditions. The system APT shall consist of the field operation of the system in a manner that is in full accordance with project requirements, the plans, and applicable standards. The APT shall commence only after the system acceptance test plan and final software, including source code, have been reviewed and approved by CTDOT/CTDMV.
- C. No intermittent failure shall be permitted to persist during the APT period except for designated server outages. If such problems are encountered, the test shall be terminated and restarted after the cause of the intermittent failure is identified and removed from the VSF system. The system may be shut down for the purposes of testing and correcting identified deficiencies. For each period of system shut down, the scheduled 60-calendar day APT shall be extended for the same period of time. If the total number of system shut downs exceeds three during the 30-calendar day test period, the system APT shall be repeated for the full 30-calendar day period.

- D. Software required to operate the VSF system and diagnose malfunctions of hardware and software shall be supplied by the Contractor and approved by CTDOT/CTDMV. A copy of system operation and diagnostic software shall be supplied to the CTDOT/CTDMV with full documentation. The Contractor shall correct any failure in the hardware or the software supplied by the Contractor at no additional cost to the CTDOT. The Contractor shall submit to CTDOT failure report logs to demonstrate that error rates are within the requirements.
- E. Equipment configurations and software shall not be changed during the APT. If a configuration or software change must occur, the test must be restarted. The Contractor shall certify the configuration and software of elements prior to the start of the APT.
- F. The Contractor shall ensure that the VSF data shall be provided at least 99% of the time, excluding any failure of utility power. These metrics shall be addressed as part of the Contractor's performance monitoring and quality assurance plan. Failure to comply with the requirements included in the performance monitoring and quality assurance plan shall amount to the Contractor paying Liquidated Damages as per the CTDOT's Standard Specification for Road and Bridge Construction.
- G. Corrective action for a failure shall be a part of the documentation process. CTDOT/CTDMV shall approve any corrective action.
- H. The Contractor shall be responsible for repairing and replacing hardware and software used on the project that has become defective during the APT. Repairs made shall conform to the plans submitted by the Contractor as part of the project design and construction process. The Contractor shall be responsible for costs associated with the maintenance, repair, or replacement of the equipment.
- I. In the event that more than one APT is necessary, the Contractor shall be responsible for costs.

7.20.5 Final VSF System Inspection

Prior to final acceptance, the Contractor shall repair and replace components/software that may have become defective during the APT. Final VSF system software and source code shall be submitted to CTDOT/CTDMV prior to final inspection. Software and source code will be the property of and for the sole use by CTDOT/CTDMV. Repairs made shall conform to the plans submitted by the Contractor as part of the design process and this scope of services. CTDOT/CTDMV will perform the final inspection of the VSF system in the presence of a representative of the Contractor.

7.20.6 Final Acceptance Performance Test Report

The CTDOT/CTDMV will generate a final report based on the results of the APT and VSF final system inspection. The Contractor shall review and comment on the final APT report. Once the Contractor has addressed comments and deficiencies noted in the final report to the satisfaction of CTDOT/CTDMV, CTDOT will issue a formal notification of VSF system acceptance. At such time, the CTDOT will assume VSF system ownership, and the Contractor shall become responsible for the hardware and software warranties and maintenance.

7.20.7 Corrective Action Plan

The Contractor shall generate a plan to correct any deficiencies noted by CTDOT in the final APT report. In some cases, corrective action may not be required if analysis of the reported anomaly by CTDOT/CTDMV does not constitute a system failure. At a minimum, the corrective action plan prepared by the Contractor and approved by CTDOT/CTDMV, shall address each discrepancy in the final APT report by indicating

- A. the test procedure where the discrepancy was observed;
- B. the requirements that were not met and by how much;
- C. a description of the problem and its impact on the suitability and functionality of the VSF system;
- D. a description of possible solutions;
- E. any interim work-around procedure recommended until the problem is fixed;
- F. an estimated schedule for how long it will take to correct the problem and if necessary to test the software; and
- G. CTDOT/CTDMV resources needed to support the Contractor to fix the problem.

7.21 OWNERSHIP OF DATA

CTDOT/CTDMV shall retain rights and ownership of VSF equipment, software and data collected from the VSF system at this site. Additionally, the VSF software and data shall not be shared by the VSF vendor/contractor with any entity without the expressed written permission of the state.

7.22 PRIVACY REQUIREMENTS

The Contractor shall ensure that data adheres to the Fair Information and Privacy Principles adopted by the Intelligent Transportation Society of America's (ITS America™). Data received from the VSF system shall be time stamped and encrypted prior to transmission to the designated server for security and anonymity purposes. The Contractor shall ensure that time stamped and encrypted information can be matched subsequent to encryption for the purpose of calculating link travel times. Encryption and other information protection methods shall be documented and provided to CTDOT/CTDMV prior to VSF system acceptance and implementation.

The Contractor will acknowledge that it understands the provisions of the Driver's Privacy Protection Act as codified by Section 14-10 of the Connecticut General Statutes, and will comply with all requirements of the law.

7.23 BASIS OF PAYMENT

Price and payment will be full compensation to the Contractor for work and materials specified in this section

INNOVATIVE TECHNOLOGY DEPLOYMENT: DEVELOPMENT OF A VIRTUAL SCREENING
FACILITY PILOT PROJECT FOR CT'S COMMERCIAL VEHICLE ENFORCEMENT PROGRAM
LIST OF TECHNOLOGICAL COMPONENTS AND DATA MODULES

8.0 IMPLEMENTATION TIME FRAME AND COST ESTIMATE

This section of the report provides an implementation time frame and a cost estimate for the pilot project for preliminary planning purposes. This project involves the selection, purchase and installation of VSF equipment, installation of utilities services including fiber optics and electricity, highway paving and installation of an in-pavement WIM system, and the integration of information collected onsite with Connecticut and national databases for real-time commercial vehicle enforcement. The project integrator is the lynchpin for achieving a successful installation that provides accurate information rapidly in an easy-to-use format for real-time commercial vehicle enforcement. The integrator's involvement in project design, equipment selection, and construction, as well as preventative maintenance for VSF operations, is an important consideration for VSF development.

Therefore, considering the complexity of the project and a preference for early contractor involvement in project design, CTDOT should consider alternative contracting methods for this project.¹⁹ Table 8.0 provides an overview of the expected benefits of using the design-build contracting methodology. Also, consideration should be given to engaging a VSF specialist as a consulting engineer for the preliminary project design, including development of the Base Technical Concept (BTC) for use in the contractor selection process, as well as for technical support for conducting the Acceptance Performance Test at the end of the project.

TABLE 8.0. EXPECTED BENEFITS FROM USE OF DESIGN-BUILD CONTRACTING METHODOLOGY FOR SELECTED PROJECT TRAITS

Project Traits	Expected Benefits Derived from Use of Design-Build Contracting Methodology
Risk Management	Enhanced based on assignment of risk to most appropriate party with design-build team working with common focus, as well as requirements for Acceptance Performance Test (APT), warranties, and follow-on preventative maintenance contract.
Constructability	Greatly reduced risk to CTDOT. Provides CTDOT/CTDMV with a coordinated design-build team, comprehensive approach for design, construction and system integration to achieve desired VSF performance and outcome.
Collaboration	Enhanced through the design and construction process.
Owner Control	Provided through the BTC and APT.
Innovation	May be realized, especially in the area of system integration and reporting.
Construction Quality	Early involvement of the design-build team in project design should help to achieve high level of construction quality.
Schedule Acceleration Completion	Reduced overall project duration; possible to start construction tasks during the design phase including design and installation of fiber optic and electrical power service, and fabrication of the gantry. Also, during the construction phase, the timing of the construction of the control pavement.
Competitive Pricing	Provides for use of best value proposal selection process with project pricing considered in context of technical scoring.
Price Certainty	Well-defined BTC and early involvement of design-build team will help to provide price certainty.

¹⁹ Strategies for Improving Transportation Project Delivery Performance, Connecticut Academy of Science and Engineering, September 2016; <http://www.ctcase.org/reports/Project-Deliverability/ProjectDeliverability.pdf>

8.1 TIME FRAME

The design-build contracting methodology was used to develop the time frame for the project's design and construction for project planning purposes. The project time frame shown in Table 8.1 begins as of the project start date for the selected design-build contractor. The table shows project phases and task durations in calendar days, the lead entity for conducting a task, and identifies project tasks that are in a critical path, including:

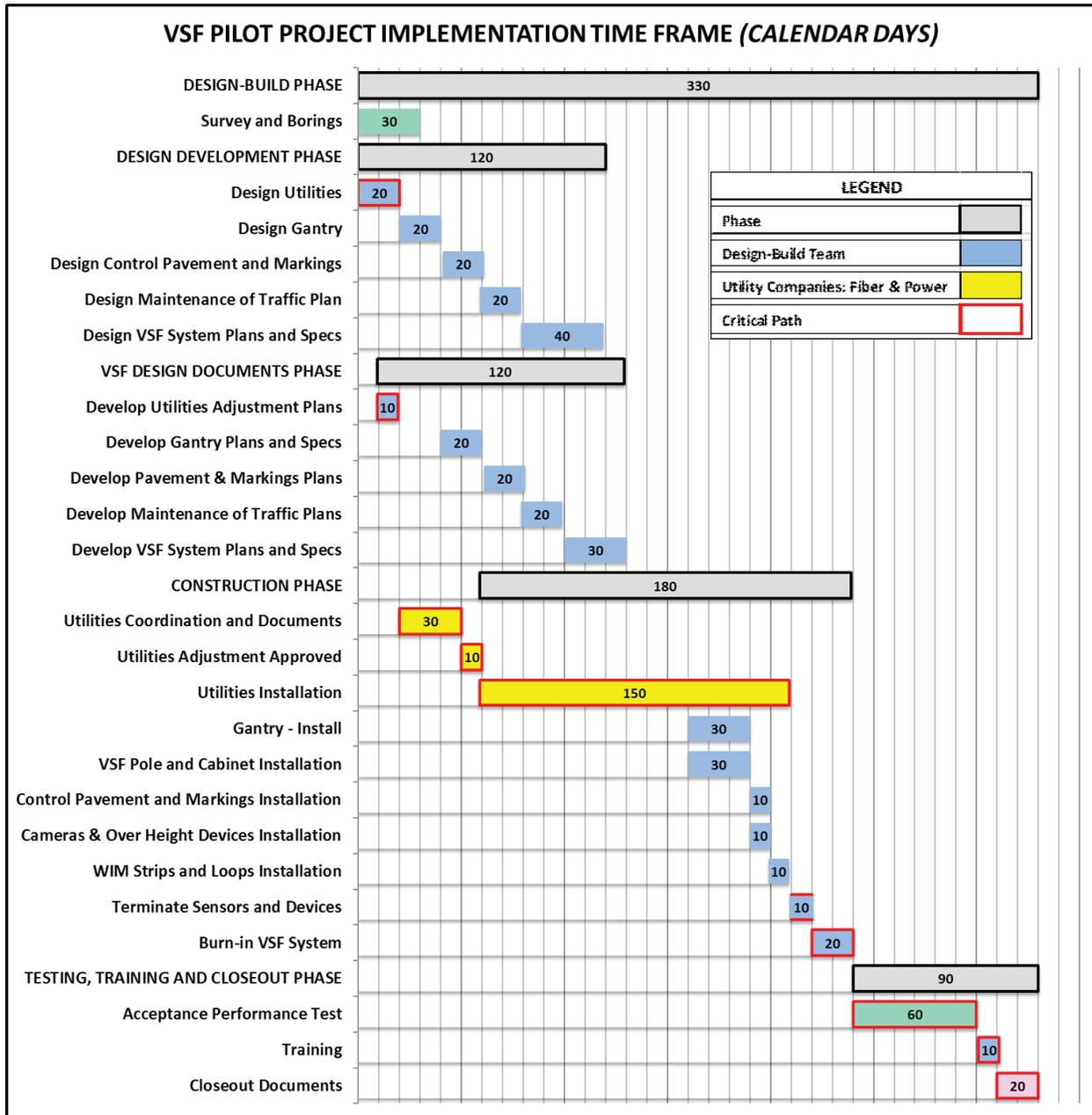
- Fiber optic utility service coordination including design plan development and approval. Service will be installed from a service point at the VSF site located near the VSF control cabinet to a designated server to be determined by CTDOT/CTDMV in consultation with the fiber optic provider.
- Electric power utility coordination and installation at the VSF site.
- Connection of sensors and devices to the VSF controller located in the VSF cabinet.
- Burn-in VSF system testing in preparation for the APT.
- Conducting the APT.
- Training staff in the use and maintenance of the VSF system.
- Completion of all closeout documents for final project acceptance.

Other time-sensitive aspects of this project may include:

- Gantry design, fabrication and installation over the roadway at the VSF site.
- Control pavement construction to coincide with best time of year to assure quality pavement construction to achieve necessary smoothness for WIM accuracy.
- Site survey and borings are shown at the design-build team's start of work. However, CTDOT may decide to complete this task during preliminary design to provide proposers with the results for use in proposal development.

INNOVATIVE TECHNOLOGY DEPLOYMENT: DEVELOPMENT OF A VIRTUAL SCREENING FACILITY PILOT PROJECT FOR CT'S COMMERCIAL VEHICLE ENFORCEMENT PROGRAM IMPLEMENTATION TIME FRAME AND COST ESTIMATE

TABLE 8.1. VSF PILOT PROJECT IMPLEMENTATION TIME FRAME (CALENDAR DAYS)
 BASED ON USE OF DESIGN-BUILD CONTRACTING METHODOLOGY



The foundation for the preliminary design and development of the BTC is provided in this report. Additional information will be needed to complete the BTC. A well-defined BTC will provide the best potential for clarity, price certainty, fewer change orders and shorter overall duration for project completion.

The first task within the design-build process can be field survey and borings as shown in the time frame above. However, to further reduce project duration of the design-build construction phase, this task could be brought forward into the preliminary design phase of the project.

Survey and borings information reduce risk of unknowns for proposal development of design-build teams.

8.2 ESTIMATED COST OF EQUIPMENT AND INSTALLATION, CONSTRUCTION, AND PREVENTATIVE MAINTENANCE

This section of the report provides a high-level planning cost estimate (Table 8.2) for the VSF Pilot Project to be located on I-91 southbound just north of the Route 510 overpass including: (1) equipment, installation and construction, and (2) preventative maintenance and post-construction costs. The cost estimate does not include project design cost.

The preventative maintenance cost estimate includes tasks necessary to maintain the operation of the VSF at a level meeting or exceeding contractual standards. These tasks include maintenance of sensors and cameras, and the controller, devices, and systems provided by the integrator.

Maintenance of sensors and cameras that are directly impacted by the environment comprise the largest percentage of the cost of preventative maintenance. However, since many systems utilize the same or similar sensors and cameras, the cost differential for maintenance between vendors is decreasing. The greatest cost differential for preventative maintenance – a smaller percentage for the total cost – is for the controller, devices, and systems provided by the integrator.

INNOVATIVE TECHNOLOGY DEPLOYMENT: DEVELOPMENT OF A VIRTUAL SCREENING FACILITY PILOT PROJECT FOR CT'S COMMERCIAL VEHICLE ENFORCEMENT PROGRAM IMPLEMENTATION TIME FRAME AND COST ESTIMATE

TABLE 8.2. COST ESTIMATE

COST ESTIMATE FOR CONSTRUCTION OF E-SCREENING PILOT PROJECT					
PAY ITEM NUMBER	PAY ITEM NAME AND DESCRIPTION	UNIT OF MEASURE	UNIT PRICE *	QUANTITY	TOTAL COSTS
1220027	WORK ZONE SIGNS: 30 Days Total	EACH DAY	\$ 21.51	30	\$ 645
1205100	CHANNELIZING DEVICE: For through traffic around the work area	EACH DAY	\$ 130.75	30	\$ 3,923
1117101	HIGH INTENSITY FLASHING LIGHTS: For through traffic around the work area	EACH DAY	\$ 2,617.21	30	\$ 78,516
219001	SEDIMENT BARRIER: Protect right ditch	LINEAR FEET	\$ 7.51	1,250	\$ 9,388
	INLET PROTECTION SYSTEM: Protect median inlets	EACH	\$ 50.00	4	\$ 200
151	CLEARING & GRUBBING: As needed for installation of Gantry, Guardrail, Service Slab...	LUMP SUM	\$ 10,000.00	1	\$ 10,000
401156	REGULAR EXCAVATION: Remove 5 Lanes of Asphalt Pavement: 12' X 1,100' X 6"	SQUARE YARDS	\$ 10.80	2,000	\$ 21,600
	EMBANKMENT: Around Gantry on right end for Conrete Service Slab under Pole-Mounted Cabinet	CUBIC YARDS	\$ 71.00	15	\$ 1,065
	SUPERPAVE ASPHALTIC CONCRETE: WIM Control Pavement - 1100' by full 12' lane width (Control Pavement Design Draft Needed)	TONS	\$ 212.00	690	\$ 146,280
	MISCELLANEOUS ASPHALT PAVEMENT: From shoulder to back side of Guardrail	SQUARE YARDS	\$ 50.00	150	\$ 7,500
406200	CLEANING & SEALING JOINTS: For existing Concrete Base	LINEAR FEET	\$ 26.90	2,700	\$ 72,630
921002	CONCRETE SIDEWALK AND DRIVEWAYS, 4" THICK: For Concrete Service Slab under Pole-Mounted Cabinet	SQUARE YARDS	\$ 21.08	3	\$ 63
703010	RIPRAP, SAND-CEMENT: For area around Concrete Service Slab	CUBIC YARDS	\$ 93.46	10	\$ 935
914	GUARDRAIL - ROADWAY THRI-BEAM: Protect Gantry structure - right end of structure	LINEAR FEET	\$ 57.96	150	\$ 8,694
911918	GUARDRAIL END ANCHORAGE ASSEMBLY- FLARED: Protect Gantry structure - right end of structure	EACH	\$ 1,925.00	2	\$ 3,850
953002	PERFORMANCE TURF, SOD: Around miscellaneous asphalt & Concrete Service Slab	SQUARE YARDS	\$ 2.64	178	\$ 470
1209586	RETRO-REFLECTIVE PAVEMENT MARKERS: Both sides of center lane	EACH		60	\$ 1,000
1209050	PAINTED PAVEMENT MARKINGS, FINAL SURFACE: Solid yellow, solid white & stiped white	LINEAR FEET	\$ 3.71	4,400	\$ 16,324
	GANTRY: For Cameras and Strobes. Includes cost of structure and foundations (Note: Option for CTDOT to add passive or DMS signs to this Gantry)	LUMP SUM	\$ 325,000.00	1	\$ 325,000
1111412	INDUCTIVE LOOPS: For WIMS and Cameras processing	EACH	\$ 13,383.00	6	\$ 80,298
1111423	WIM, PIZOELECTRIC SENSORS (2M): 2 Strips per lane	EACH	\$ 15,800.00	6	\$ 94,800
1114201	CABINET, POLE MOUNT, 1 BACKPLANE: For housing all electronics	EACH	\$ 885.60	1	\$ 886
90093	CONDUIT, OPEN TRENCH: For power, fiber, and control wire	LINEAR FEET	\$ 5.28	1,500	\$ 7,920
100104	FIBER OPTIC CABLE, INSTALL, UNDERGROUND, 2-12 FIBERS: from service point to VSF site	LINEAR FEET	\$ 150.00	500	\$ 75,000
	PULL & SPLICE BOX, Furnish & Install (F&I), 13" x 24" COVER SIZE: 250' Maximum	EACH	\$ 1,100.00	15	\$ 16,500
	PULL & SPLICE BOX, F&I, 24" x 36" COVER SIZE: For fiber splice and loop storage	EACH	\$ 1,500.00	4	\$ 6,000
	ELECTRICAL POWER SERVICE, F&I, UNDERGROUND, METER FURNISHED BY POWER COMPANY: On Depot Hill Road at Northwest corner of Overpass	LUMP SUM	\$ 10,000.00	1	\$ 10,000
	LIGHTING CONDUCTORS, F&I, INSULATED, NO. 8 - 6	LINEAR FEET	\$ 9.00	500	\$ 4,500
	LIGHTING CONDUCTORS, F&I, INSULATED, NO. 6 - 4	LINEAR FEET	\$ 10.00	500	\$ 5,000
	USDOT# CAMERA (1 FOR RIGHT LANE)	EACH	\$ 31,500.00	1	\$ 31,500
	LPR CAMERA (1 PER LANE)	EACH	\$ 28,000.00	3	\$ 84,000
	CONTROLLER, SOFTWARE AND TRAINING	EACH	\$ 163,000.00	1	\$ 163,000
SUBTOTAL					\$ 1,287,486
975003	MOBILIZATION (10% of Subtotal Cost)	LUMP SUM	\$ 128,748.60	1	\$ 128,749
971001	MAINTENANCE OF TRAFFIC: 30 Days Total (10% of Subtotal Cost)	LUMP SUM	\$ 128,748.60	1	\$ 128,749
CONSTRUCTION SUBTOTAL					\$ 1,544,983
	INITIAL CONTINGENCY AMOUNT, DO NOT BID (20% of Construction Subtotal)	LUMP SUM	\$ 257,497.19	1	\$ 257,497
CONSTRUCTION GRAND TOTAL					\$ 1,802,480
COST ESTIMATE FOR VSF POST CONSTRUCTION ANNUAL COST					
PAY ITEM	PAY ITEM NAME AND DESCRIPTION	UNIT OF MEASURE	UNIT PRICE *	QUANTITY	TOTAL COSTS
UTILITIES	FIBER COMMUNICATIONS (5-Year Lease; includes build-out and monthly service)	Monthly	\$ 2,000.00	12	\$ 24,000
UTILITIES	ELECTRICAL POWER (Estimated Monthly kWh: 2000; Rate: \$0.145/kWh)	Monthly	\$ 290.00	12	\$ 3,480
UTILITIES ANNUAL COST SUBTOTAL					\$ 27,480
	VSF PREVENTIVE MAINTENANCE: Validate weights, check grout, check loops, clean cameras, check filters, with Manlift. No maintenance of traffic included. (Planned PM)	ANNUAL	\$ 8,000.00	1	\$ 8,000
	VSF REPAIRS (Unplanned Repairs)	ANNUAL	\$ 3,300.00	1	\$ 3,300
VSF MAINTENANCE ANNUAL SUBTOTAL					\$ 11,300
POST CONSTRUCTION ANNUAL COST GRAND TOTAL					\$ 38,780
NOTE: * Most of the Unit Prices were provided by CTDOT; others were estimated by the CASE Reseach Team					

INNOVATIVE TECHNOLOGY DEPLOYMENT: DEVELOPMENT OF A VIRTUAL SCREENING
FACILITY PILOT PROJECT FOR CT'S COMMERCIAL VEHICLE ENFORCEMENT PROGRAM
IMPLEMENTATION TIME FRAME AND COST ESTIMATE

9.0 RECOMMENDATIONS AND CONCLUDING REMARKS

This study presents an implementation plan for development of a pilot VSF for use by CTDOT/CTDMV. The pilot VSF will be used to test various technologies to determine their value in enhancing commercial vehicle size, weight and safety enforcement in Connecticut. Three sites were analyzed for selection as the pilot project. Based on the analyses, the I-91 SB at Route 510 site was selected as the pilot VSF project by CTDOT/CTDMV.

RECOMMENDATIONS

The study recommendations are shown in two categories: those related to the VSF pilot project, and additional recommendations regarding the commercial vehicle enforcement program based on the research and analyses conducted throughout this study.

9.1 VSF PILOT PROJECT

Based on the analyses conducted, CTDMV/CTDOT should plan, design, construct and operate a pilot VSF at the proposed site for the purpose of testing VSF technologies for potential future use at additional VSF sites and existing weigh stations. The following suggestions are offered for consideration by CTDOT and CTDMV:

- CTDMV/CTDOT: Evaluate the pilot VSF through the collection and analyses of data using the proposed performance measures
 - Review the proposed performance measures identified in Chapter 7 with the VSF contractor and revise as necessary to assure that data collected and reported will provide system analyses needed for decisions on deployment of additional VSFs.
 - Report on the impact of the pilot VSF based on the performance measures.
 - Use results of the pilot project for planning additional deployments of VSF technologies and functionalities.
- CTDOT: Utilize traffic data for real time traffic management and future planning needs
- CTDMV/CTDOT/CSP: Establish an interagency Memorandum of Understanding (MOU) to formalize responsibilities of CTDMV/CTDOT and CSP for the planning, design, construction and operation and reporting for the pilot VSF project as part of an interagency MOU for formalizing overall responsibilities for the Commercial Vehicle Enforcement Program (see Additional Recommendations).

9.2 ADDITIONAL RECOMMENDATIONS

The following additional recommendations are included as additional opportunities for consideration by CTDMV/CTDOT to improve and enhance the state's commercial vehicle enforcement program:

- Establish an interagency MOU between CTDMV, CTDOT and CSP to create a multi-

agency working group to formalize each agency's responsibilities for the Commercial Vehicle Enforcement Program for the purpose of collaboration, cooperation, and coordination to achieve the program's overall size, weight, and safety goals. Suggested responsibilities of the working group include:

- o Planning, operation, and management of the Commercial Vehicle Enforcement Program and the facilities that support the program – weigh stations and VSFs. Also, development of a program budget and annual reporting (budget vs. actual) for enforcement operations, maintenance of facilities and systems, and capital projects.
- o Development of a strategic plan for continuous improvement of the Commercial Vehicle Enforcement Program, including but not limited to:
 - ◆ goals/strategies/outcomes;
 - ◆ feasibility evaluation for siting additional VSFs or other facilities;
 - ◆ design and construction guidelines for development of additional VSFs and upgrading of existing weigh stations;
 - ◆ performance measures for operation of the program; include systemic success measures (program outcomes: progress in changing behavior such as accidents, injuries, and fatalities involving commercial vehicles, and pavement preservation); and
 - ◆ reporting on performance measures, and other factors such as VSF system operation.
- o Oversight for the development of the pilot VSF, other VSFs, and use of VSF technologies and functionalities to enhance existing weigh stations.
- The following provides guidance for prioritizing the development and installation of additional VSFs, and VSF technologies and functionalities at existing weigh stations:
 - o Table 9.0 shows the annual average percentage of overweight citations issued at each of the existing weigh stations for fiscal years 2009 – 2016, calculated by dividing the annual average number of overweight citations issued by the average total number of commercial vehicles weighed. This information provides a foundation for considering the need for additional deployments of VSF technologies. This data shows that the percentage of commercial vehicles issued overweight citations is very low as compared with the number of vehicles weighed for all weigh stations in Connecticut. The results of pilot VSF enforcement operations will be useful in determining the value of screening commercial vehicles for weight and safety inspection in Connecticut. As has been shown in other states, screening has been effective in improving commercial vehicle enforcement effectiveness.

INNOVATIVE TECHNOLOGY DEPLOYMENT: DEVELOPMENT OF A VIRTUAL SCREENING FACILITY PILOT PROJECT FOR CT'S COMMERCIAL VEHICLE ENFORCEMENT PROGRAM
RECOMMENDATIONS AND CONCLUDING REMARKS

TABLE 9.0: ANNUAL AVERAGE PERCENTAGE OF OVERWEIGHT CITATIONS ISSUED AT EXISTING WEIGH STATIONS (FY2009 – FY2016)

Weigh Station (ordered by percentage of citations issued)	Percentage of Overweight Citations Issued	Overweight Citations	Total CVs Weighed
Middletown (I-91 NB)	1.36%	455	33,397 (Static Scale Only)
Greenwich (I-95 NB)	1.0%	1,660	165,609 (WIM & Static Scale)
Waterford (I-95 SB)	0.93%	133	14,337 (Static Scale Only)
Danbury (I-84 EB)	0.84%	505	59,811 (Static Scale Only)
Waterford (I-95 NB)	0.56%	125	22,239 (Static Scale Only)
Union (I-84 WB)	0.12%	316	262,871 (WIM & Static Scale)
<p>Notes:</p> <ol style="list-style-type: none"> 1. Data shown are annual averages for the period of FY2009 – FY2016 2. Static Scale Only: CVs are weighed only on static scales at the Danbury, Middletown, and Waterford Weigh Stations 3. WIM & Static Scale: CVs are weighed on ramp WIM and static scales at Greenwich and Union Weigh Stations 			

- o If it is determined that the pilot VSF project was successful in improving commercial vehicle enforcement effectiveness, it is suggested that testing VSF technologies and functionalities at one of the state's existing weigh stations should be the next priority.
 - ◆ It is suggested that the Greenwich Weigh Station (I-95 NB) be considered as the next site to test VSF technologies. This site has the greatest amount of commercial vehicle traffic of all of the state's weigh stations. Typically, when the weigh station is open, commercial vehicles entering the weigh station quickly queue onto the mainline resulting in frequent closing and opening of the station. This VSF installation would include a mainline sorting system to improve safety and effectiveness and enable the manually operated ramp WIM to be decommissioned. It is noted that this installation requires coordination with New York State for installation of signage in New York directing commercial vehicles to use the right lane only.
 - ◆ If installation of VSF technologies at the Greenwich Weigh Station is not possible, then the Middletown Weigh Station (I-91 NB) should be considered as the next test site. As shown in Table 9.0, the Middletown Weigh Station has the highest annual average percentage of overweight citations issued compared to the total number of commercial vehicles weighed. This section of I-91 NB also has a high level of commercial vehicle traffic, including both intrastate and interstate. This VSF installation would include a mainline sorting system to improve safety and effectiveness. This project could potentially be considered as part of the CTDOT proposed I-91/I-691 project.
- o Considerations for prioritizing development of additional VSF installations based on the results of the pilot VSF project and an initial weigh station VSF enhancement project are as follows.

- ◆ Two VSF sites were considered for the pilot project and are potential sites for development of additional VSFs.
 - I-95 SB at the Rhode Island border. This site is just past Exit 93 with the Mystic/North Stonington Rest Area identified to serve as the primary direct enforcement area, along with the I-95 Southbound Waterford Weigh Station being available as a secondary direct enforcement site. An advantage of deployment of a VSF at this location is that enforcement presence would be available before commercial vehicles travel over the Gold Star Bridge in Groton.
 - I-395 SB in the vicinity of Plainfield Service Plaza (identified to serve as the primary direct enforcement area) and U.S. Route 6. This site is currently not protected with a weigh station, with commercial vehicle enforcement only provided through periodic mobile enforcement. Installation of a VSF site would provide enforcement coverage for southbound commercial vehicle traffic entering the state from Massachusetts and Rhode Island, and may serve to reduce the number of vehicles that use I-395 southbound in an effort to bypass the Union Weigh Station on I-84 westbound.
- ◆ Connecticut's weigh stations, in addition to the Greenwich Weigh Station and the Middletown Weigh Station previously discussed.
 - Danbury Weigh Station (I-84 EB). This weigh station is very close to the New York State border. It is co-located in a rest area used by the public. A VSF installed at this location to support enforcement at the weigh station would need to be located in New York State. Agreement with New York State would be needed. An alternative could be the development of a VSF as part of the I-84/Route 7 project, pending identification of an acceptable site to replace the Danbury Weigh Station.
 - Union Weigh Station (I-84 WB). This weigh station is close to the Massachusetts border. Currently, a ramp WIM is used for screening vehicles to be weighed on a static scale. A mainline WIM is installed at this site, but it is not operational at this time. VSF technologies would be installed to enhance enforcement, including replacement of the mainline WIM and decommissioning of the ramp WIM. Additionally, installation of a VSF at this location to enhance enforcement for I-84 EB should be considered, with the weigh station being used as the primary direct enforcement area.
 - Waterford Weigh Station (I-95 NB). This weigh station has limited space for enforcement. A VSF installed at this location with screening functionalities would support enforcement and improve the effectiveness of the weigh station. The proposed I-95 expansion project in southeastern Connecticut may impact the future of this weigh station, and could be a consideration in a decision regarding investment in improvements.
 - Waterford Weigh Station (I-95 SB). A decision on enhancing this

weigh station with VSF functionalities should be based on the installation of the proposed VSF on I-95 SB at the Rhode Island border. If this VSF is developed, then this weigh station would serve as a secondary direct enforcement site for the VSF. However, similar to the Waterford Weigh Station NB, the proposed I-95 expansion project may impact a decision to invest in improvements at this weigh station.

- Utilize CTDOT WIM planning data for commercial vehicle enforcement and data analysis.
 - Provide access to planning WIM site data in real-time for CTDMV/CSP commercial vehicle enforcement
 - Use WIM planning data and VSF data for trend analysis of a systemic performance measure on the weights of commercial vehicles traveling on Connecticut highways.
- Consideration of additional functionalities to support commercial vehicle enforcement include:
 - Development of E-permits and integration into the VSF system.
 - Integration of hazmat readers into VSF sites that are upstream from a weigh station or a VSF that uses a sorting strategy. Hazmat readers currently are effective if used in the right lane only.
 - Observation cameras to monitor bypass routes around weigh stations and VSFs. These cameras would provide enforcement staff with the capability to remotely monitor bypass routes with dispatch for enforcement only when necessary.
 - Use of a self-contained mobile enforcement trailer, similar to that used by Massachusetts and Rhode Island, that provides VSF functionalities for mobile enforcement use on interstates and secondary roads throughout the state.
- Add functionality for Amber Alerts at VSF sites. This requires an additional LPR in each lane to read rear license plates.
- Collaborate with other states to enhance the effectiveness of Connecticut's Commercial Vehicle Enforcement Program and regional commercial vehicle enforcement.
 - Align commercial vehicle codes, where possible, to minimize conflicts.
 - Data sharing to provide adjacent states with analysis of VSF data and Connecticut's enforcement results, including such information by state registration. Secure this same information from other collaborating states, if available.
 - Development of facilities at state borders.
- Conduct an analysis of the Judicial Branch's disposition of commercial vehicle and driver citations issued by enforcement officers
 - Explore opportunities to improve the percentage of guilty verdicts and fine collections through a review of commercial vehicle enforcement procedures and processes, judicial system procedures and processes, and the fine structure.

- Consider legislative initiatives to amend state statutes related to weigh station staffing and reporting requirements.

- o *CGS Chapter 248, § 270c [1-4]: Official Weighing Areas. Staffing Requirements*

This statute mandates weigh station shift staffing requirements. It is suggested that legislatively mandated staffing requirements should be eliminated and the balance of this statute should be revised to enable staffing flexibility that will provide for more strategic randomized enforcement strategy with a goal of improving the effectiveness of the commercial vehicle enforcement program for weigh station, VSF, and mobile enforcement.

- o *CGS Chapter 248, § 270f: Weigh Station Logs*

Revise legislatively mandated semi-annual weigh station reporting requirements to be consistent with the established performance measures for the commercial vehicle enforcement program.

- o *CGS Chapter 248, § 270e: Program to Implement Regularly Scheduled and Enforced Hours of Operation for Weigh Stations*

Review and revise legislatively mandated annual planned enforcement program reporting requirements to ensure that required reporting information allows for random scheduling of weigh station staffing.

CONCLUDING REMARKS

The development of a VSF involves design, construction and installation of equipment typical of many highway projects. However, the integration of various VSF functions adds complexity to the development and use of a VSF for real-time commercial vehicle enforcement and highway planning.

The integrator is the project partner with the responsibility to assure that the information collected at the VSF site is analyzed seamlessly in real time to provide enforcement officers with results needed to screen commercial vehicles for weight, size, and safety inspection. The speed, accuracy, and ease of use of the information provided are key elements of a successful VSF. Additionally, a critical element of the integrator's system is the ability to analyze 24/7 VSF data collected to enable strategic development and refinement of enforcement strategies.

APPENDIX A VIRTUAL WEIGH STATION DEPLOYMENT

The following provides information on typical virtual weigh station deployment as depicted in two figures from the report: State of the Practice - Smart Roadside Initiative Gap Analysis - Final, March 2014; US Department of Transportation, Intelligent Transportation Systems Joint Program Office. (Source: Cambridge Systematics, Inc., based on observations taken at mainline screening facilities, including Martin County, Florida; and Wildwood, Florida, 2014)

FIGURE A.1: OPERATIONAL FLOW OF TYPICAL VIRTUAL WEIGH STATION DEPLOYMENT

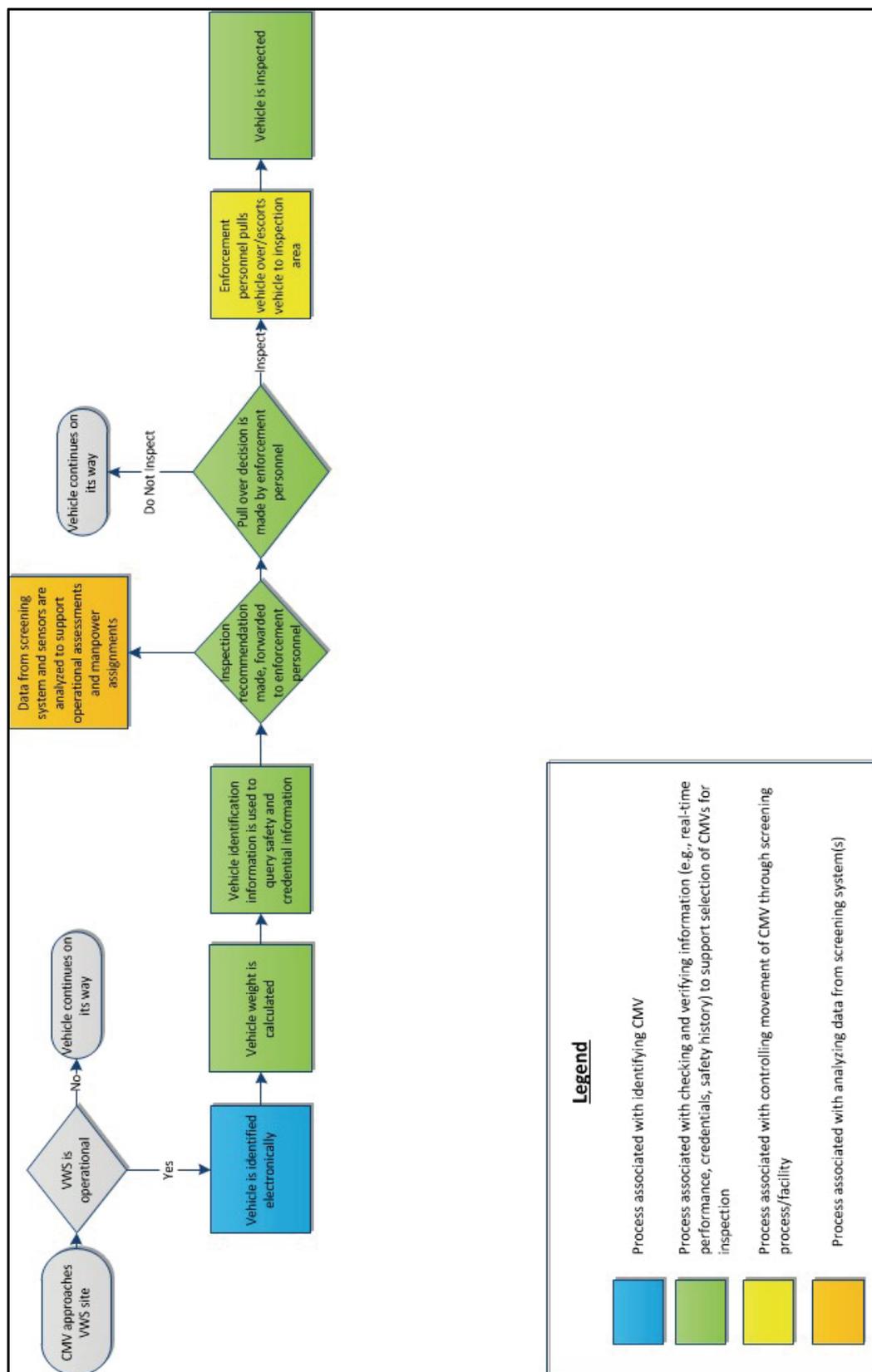
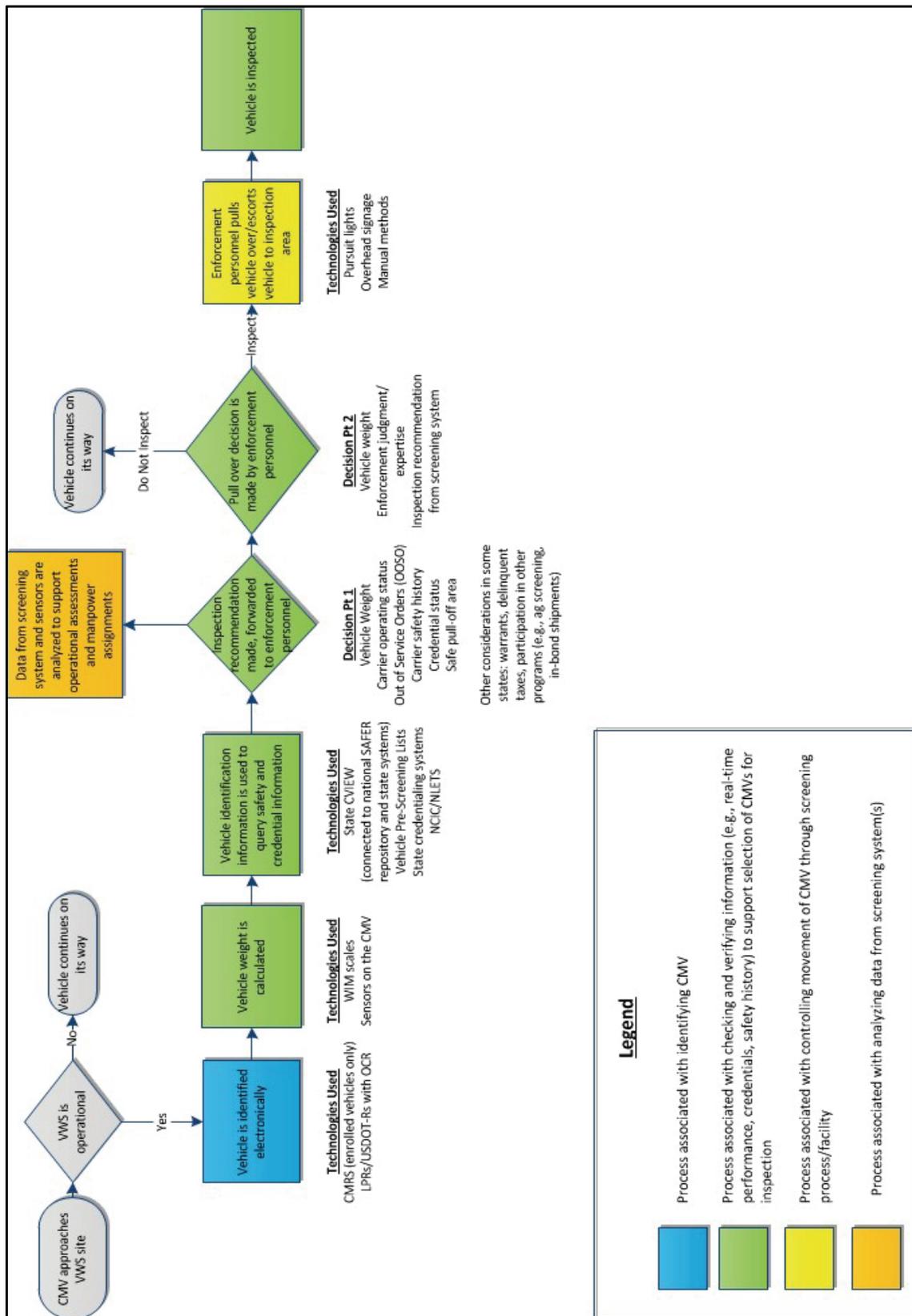


FIGURE A.2: TECHNOLOGIES USED TO SUPPORT VIRTUAL WEIGH STATION DEPLOYMENTS



APPENDIX B
COMMERCIAL VEHICLE ENFORCEMENT DATA:
MOBILE ENFORCEMENT SAMPLING EXERCISES

SUMMARY REPORTS

CASE STUDY "WOLFPACK": SUMMARY: CONDUCTED ON I-91 SB @ ROUTE 510

CASE STUDY "WOLFPACK" #2: SUMMARY: CONDUCTED ON I-395 SB @ U.S. ROUTE 6



STATE OF CONNECTICUT
Department of Motor Vehicles
60 State Street
Wethersfield, Connecticut 06161

Contact:
(860) 263-5446

June 27, 2017

**CASE Study “WOLFPACK”
I-91 SB @ Route 510**

SUMMARY

The Connecticut Department of Motor Vehicles, Commercial Vehicle Safety Division, Central Truck Team conducted focused enforcement on June 13th, 14th, and 15th on I-91 SB in the vicinity of the Route 510 overpass and Exit 42 (Route 159) as part of the CASE CVISN Escreening Pilot Project. Four Inspectors and one Sergeant were assigned to the 3-day detail. Detail hours were: Tuesday June 13th 0330-1330 hours; Wednesday June 14th 0530-1530 hours; and Thursday June 15th 0530-1530 hours.

Inspection results show that during the 3-days they stopped and inspected 89 trucks, and their drivers. Of these stops, 26 vehicles and 11 drivers were declared out-of-service. In total there were 268 violations discovered. In total 31 tickets were issued resulting in potential fines of \$6,932.

Driver out-of-service violations were: 4 - hours of service; 1 - medical certification; 1 - possession of controlled substances; and 6 - various other violations.

Vehicle out-of-service violations were: 29 - brakes; 7 - load securement; 5 - lighting; 4 - tires; 1 - fuel system; and 2 - various other violations.

INSPECTION SUMMARY

Level 1: 13 (14.6%)

Level 2: 47 (52.81%)

Level 3: 29 (32.58%)

Total: 89

Out-of-Service/Violations

Vehicles OOS: 26 (43.33%)

Drivers OOS: 11 (12.36%)

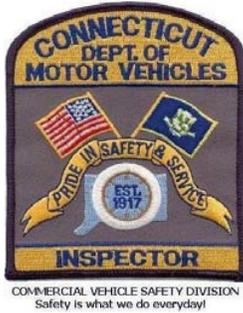
Total all
violations: 268 (3.01 violations/insp.)

Note: Vehicle OOS based on level 1 and 2 inspections (60).

###END###

Lt. Donald Bridge,
Jr. (Updated 8/24/2017)

Department of Motor Vehicles



STATE OF CONNECTICUT
Department of Motor Vehicles
60 State Street
Wethersfield, Connecticut 06161

Contact:
(860) 263-5446

July 27, 2017

CASE Study "WOLFPACK" #2 I-395 SB @ Route 6

SUMMARY

The Connecticut Department of Motor Vehicles, Commercial Vehicle Safety Division, East Truck Team conducted focused enforcement on July 18th, 19th, and 20th on I-395 SB in the vicinity of Route 6 and the Plainfield Service Plaza as part of the CASE CVISN Escreening Pilot Project. Three Inspectors and one Sergeant were assigned to the 3-day detail. Detail hours were: Tuesday July 18th 0300-1300 hours; Wednesday July 19th 0500-1500 hours; and Thursday July 20th 0500-1500 hours.

Inspection results show that during the 3-days they stopped and inspected 48 trucks, and their drivers. Of these stops, 17 vehicles (4 towed) and 6 drivers were declared out-of-service. In total there were 290 violations discovered. In total 31 tickets were issued resulting in potential fines of \$17,719. There were 16 over weights discovered (heaviest were: 94,950; 94,800; 89,800; 86,600); 12 ticketed and 2 off loads.

Driver out-of-service violations were: 6 - hours of service; 1 - disqualified driver (license suspension); and 1 - various other violations.

Vehicle out-of-service violations were: 12 - brakes; 4 - load securement; 2 - lighting; 4 - steering; 4 - suspension; 7 - tires; and 1 - wheels.

INSPECTION SUMMARY

Out-of-Service/Violations

Level 1: 11 (22.92%)

Vehicles OOS: 17 (50%)

Level 2: 23 (47.92%)

Drivers OOS: 6 (12.5%)

Level 3: 14 (29.17%)

Total all
violations: 290 (6.04 violations/insp.)

Total: 48

Note: Vehicle OOS based on level 1 and 2 inspections (34).

###END###
Lt. Donald Bridge,
Jr. (Updated 8/24/2017)

APPENDIX C

STUDY COMMITTEE MEETINGS AND GUEST SPEAKERS

The following is a list of study committee meetings, including presentations given to the CASE study committee by guest speakers and the CASE Research Team. In the electronic version of this report, links to meeting proceedings are highlighted in blue.

DECEMBER 21, 2016 – MEETING 1

- **Welcome and Introductions**, Richard H. Strauss, CASE Executive Director
- **CTDOT Overview** – [Presentation](#)
CT DOT ITS – [Presentation](#)
 - Bureau of Policy and Planning:** Colleen Kissane, Transportation Assistant Planning Director; Gary Sojka, Transportation Supervising Planner; Brad Overturf, Transportation Supervising Planner
 - Bureau of Highway Operations:** Don Braman, License and Applications Supervisor, Oversize/Overweight Permit Unit; John Korte, Transportation Supervising Engineer, Office of Highway Operations
Topic: Overview and purpose of Connecticut's current weigh stations and the weight, size, and safety enforcement program
- **CTDMV Overview** – [Presentation](#)
Lt. Donald Bridge, Commercial Vehicle Safety Division
- **Study Team** – [Presentation 1 Florida Site Visit Overview](#); [Presentation 2 Work Plan](#); [CASE Florida Site Visit Summary](#)
Barry Mason, *Study Manager*, President & CEO, BGM Consulting LLC
- **Guest Speaker** – [Presentation](#)
David Baechtold, Accounts Manager, and Bob Susor, Product Manager, Mettler Toledo
Topic: Technologies and their Integration for Use in Commercial Vehicle Virtual Weight, Size, and Safety Enforcement

JANUARY 25, 2017 – MEETING 2

- **Welcome and Introductions**, Richard H. Strauss, CASE Executive Director
- **Guest Speaker** – [Presentation](#)
Jennifer R. Walton, PE, ITS Program Manager, Kennedy Transportation Center, University of Kentucky
Topic: Kentucky Automated Truck Screening System
- **Committee Member Speaker** – [Presentation](#)
Lt. Robert Nichols, Troop Commander, Commercial Vehicle Enforcement, Maine State Police
- **Guest Speaker** – [Presentation](#)
Eric Jackson, PhD, Assistant Research Professor and Director, Connecticut Transportation Safety Research Center, UConn
Topic: Weight Station Crash Information
- **Research Update** – [Jan. 18 Commissioners' Briefing](#)
Barry Mason, Study Manager, and Richard H. Strauss, CASE Executive Director

FEBRUARY 22, 2017 – MEETING 3

- **Welcome**, Richard H. Strauss, CASE Executive Director
- **Committee Member – Presentation**
Lt. Thomas Fitzgerald, MA State Police and Study Committee Member
Topic: Commercial Vehicle Weight Enforcement Training
- **Guest Speaker – Presentation**
Sam Fayez, PhD, Director, Transportation & Logistics, Productivity Apex, Inc.
Topic: Smart Roadside Initiative (SRI) Impacts Assessment
- **Guest Speaker – Presentation**
Tom Kearney, Senior Freight Specialist, USDOT-FHWA
Topic: Truck Size and Weight Enforcement Technologies, FHWA Perspective
[FHWA Presentation References](#)
[FHWA Compliance Comparative Analysis Technical Report](#)
- **Research Update – Presentation**
Barry Mason, Study Manager
Topic: Trucks Impacts

MARCH 15, 2017 – MEETING 4

- **Welcome**, Richard H. Strauss, CASE Executive Director
- **Committee Member – Presentation**
Chris Scharl, Intermodal Transportation Specialist, NYSDOT
Topic: Overview of NY State E-Screening Program
- **Guest Speaker – Presentation**
Tom Der, Director of Sales and Rod Klashinsky, Vice-President, ITS Solutions
& Special Projects, International Road Dynamics Inc.
Topic: Commercial Vehicle E-Screening Systems, Virtual Weigh Stations
- **Research Update – Presentation**
Barry Mason, Study Manager
Topic: Feasibility Analysis/Review of Technical Data

APRIL 26, 2017 – MEETING 5

- **Welcome**, Richard H. Strauss, CASE Executive Director
- **Guest Speaker – Presentation**
Thaddeus Hoffman, Program Manager, Iteris
Topic: E-Screening, Some Data Considerations
- **Research Team – Presentation**
Barry Mason, Study Manager
Topic: Appropriate Functions and Technologies
- **Virtual Site Facility Update**
Richard H. Strauss, CASE Executive Director

MAY 24, 2017 – MEETING 6

- **Welcome**, Richard H. Strauss, CASE Executive Director
- **Guest Speaker – Presentation**
Enrique Cramer, Business Development Director, Intelligent Imaging Systems
Topic: Smart Roadside & Drivewayze Technologies

- **CTDOT Study Contact – Presentation**
Brad Overturf, Transportation Supervising Engineer, Bureau of Policy and Planning
Topic: WIM Status - Traffic Monitoring
- **Guest Speaker – Presentation**
Department of Civil & Environmental Engineering, University of Nevada, Reno: Elie Y. Hajj, PhD, Associate Professor & Associate Director of WRSC, Pavement Engineering & Science Program and Raj Siddharthan, PhD, PE, Professor
Topic: Impact of Heavy Vehicles on Flexible Pavements
- **Study Update**
Barry Mason, Study Manager, and Richard H. Strauss, CASE Executive Director

JUNE 28, 2017 – MEETING 7

- **Welcome, Richard H. Strauss**, CASE Executive Director
- **Guest Speaker – Presentation**
Claudio Vecchiarino, New England Traffic Solutions; Paul Lazzarotti, Gridsmart
Topic: Gridsmart Technologies (Cameras for bypass monitoring)
- **Guest Speaker – Presentation**
Jeffrey Rice, Road & Traffic Sales Manager – Americas, Kistler Instrument Corporation
Topic: WIM Quartz Piezoelectric
- **Research Team Update – Presentation**
Barry Mason, Study Manager
Topic: Best Practices Review

JULY 19, 2017 – MEETING 7

- **Welcome, Richard H. Strauss**, CASE Executive Director
- **CTDMV Study Contact**
Lt. Donald Bridge, Commercial Vehicle Safety Division
Topic: CTDMV Data Services/Sets/Clearinghouses used for Commercial Vehicle Enforcement
- **Guest Speaker – Presentation**
Steve Vaughn, National Director of Field Operations, HELP Inc.
Topic: WIM Quartz Piezoelectric
- **Research Team Update**
Barry Mason, Study Manager
Topic: Best Practices Review (Continuation from previous Study Committee Meeting)

AUGUST 23, 2017 – MEETING 7

- **Welcome, Richard H. Strauss**, CASE Executive Director
- **Study Committee Discussion**
Barry Mason, Study Manager, and Richard H. Strauss, CASE Executive Director
Topic: Brainstorming Concepts for Recommendations

MAJOR STUDIES OF THE ACADEMY

2016

- Strategies for Improving Transportation Project Delivery Performance
- Early Childhood Regression Discontinuity Study
- Connecticut Disparity Study: Phase 3

2015

- Addressing Family Violence in Connecticut: Strategies, Tactics and Policies
- Shared Clean Energy Facilities
- Methods to Measure Phosphorus and Make Future Predictions

2014

- Energy Efficiency and Reliability Solutions for Rail Operations and Facilities
- Connecticut Biomedical Research Program: Analysis of Key Accomplishments
- Peer Review of a CL&P/UConn Report Concerning Emergency Preparedness and Response at Selective Critical Facilities
- Connecticut Disparity Study: Phase 2

2013

- Analyzing the Economic Impact of Transportation Projects
- Health Impact Assessments Study
- Connecticut Disparity Study: Phase I
- Connecticut Stem Cell Research Program Accomplishments

2012

- Strategies for Evaluating the Effectiveness of Programs and Resources for Assuring Connecticut's Skilled Workforce Meets the Needs of Business and Industry Today and in the Future
- Benchmarking Connecticut's Transportation Infrastructure Capital Program with Other States
- Alternative Methods for Safety Analysis and Intervention for Contracting Commercial Vehicles and Drivers in Connecticut

2011

- Advances in Nuclear Power Technology
- Guidelines for the Development of a Strategic Plan for Accessibility to and Adoption of Broadband Services in Connecticut

2010

- Environmental Mitigation Alternatives for Transportation Projects in Connecticut
- The Design-Build Contracting Methodology for Transportation Projects: A Review of Practice and Evaluation for Connecticut Applications
- Peer Review of an Evaluation of the Health and Environmental Impacts Associated with Synthetic Turf Playing Fields

2009

- A Study of the Feasibility of Utilizing Waste Heat from Central Electric Power Generating Stations and Potential Applications
- Independent Monitor Report: Implementation of the UCHC Study Recommendations

2008

- Preparing for Connecticut's Energy Future
- Applying Transportation Asset Management in Connecticut
- A Study of Weigh and Inspection Station Technologies
- A Needs-Based Analysis of the University of Connecticut Health Center Facilities Plan

2007

- A Study of the Feasibility of Utilizing Fuel Cells to Generate Power for the New Haven Rail Line
- Guidelines for Developing a Strategic Plan for Connecticut's Stem Cell Research Program

2006

- Energy Alternatives and Conservation
- Evaluating the Impact of Supplementary Science, Technology, Engineering and Mathematics Educational Programs

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CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING

The Connecticut Academy is a non-profit institution patterned after the National Academy of Sciences to identify and study issues and technological advancements that are or should be of concern to the state of Connecticut. It was founded in 1976 by Special Act of the Connecticut General Assembly.

VISION

The Connecticut Academy will foster an environment in Connecticut where scientific and technological creativity can thrive and contribute to Connecticut becoming a leading place in the country to live, work and produce for all its citizens, who will continue to enjoy economic well-being and a high quality of life.

MISSION STATEMENT

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- Provide information and advice on science and technology to the government, industry and people of Connecticut.
- Initiate activities that foster science and engineering education of the highest quality, and promote interest in science and engineering on the part of the public, especially young people.
- Provide opportunities for both specialized and interdisciplinary discourse among its own members, members of the broader technical community, and the community at large.

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