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Final Report for Task Order 6105

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PLANNING THE DEVELOPMENT OF A COMMERCIAL MOTOR VEHICLE VIRTUAL WEIGH STATION TECHNOLOGY TESTBED

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Final Report for PATH Task Order 6105

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ABSTRACT

This report describes the issues associated with planning the development of a technology testbed for Virtual Weigh Stations in California. These issues may be organized into the following categories: system design and architecture, operational environment, siting & location, data collection, functional requirements and options, technology requirements and options, identification of stakeholders, operational testing and evaluation (operational scenarios, performance measures, benefits & costs), and business case development. The authors took a high-level perspective in writing this report and it serves as an initial stage tool that provides a "laundry list" of VWS technology testbed issues for Caltrans to consider when the appropriate time arrives to actually implement such a testbed.

Key Words: **commercial motor vehicle, virtual weigh station, technology testbed**

EXECUTIVE SUMMARY

This report constitutes the final deliverable for PATH Project Task Order 6105 under contract 65A0208 — "Compliance & Commercial Vehicle Operators: A Systems Evaluation of the Problem & Virtual Solutions". We examine in this report the planning process for the implementation of a Virtual Weigh Station (VWS) technology testbed within California.

For the last five years California has investigated different aspects of VWS ranging from academic studies including a cost-effectiveness analysis, legal and institutional barriers to their successful implementation, and strategies for successful implementation to a prototype deployment of a VWS at the Cordelia commercial motor vehicle enforcement facility in Northern California. At this stage in its building block deployment planning approach, the State is interested in implementing a VWS technology testbed; however, current lack of funding availability for such an enterprise remains a significant issue and has precluded detailed implementation planning from moving forward at this time. Nonetheless, having such a testbed continues to be an important objective on the deployment horizon for the State and toward that end, a high-level description of the issues has been developed and serves as an initial-stage tool that provides a check-off list of VWS technology testbed issues for Caltrans to consider now as well as when the more appropriate time arrives to actually implement such a testbed.

These issues were organized into the following categories: system design and architecture, operational environment, siting and location, data collection, functional requirements and options, technology requirements and options, identification of stakeholders, operational testing and evaluation (operational scenarios, performance measures, benefits & costs), and business case development. For system design and architecture, the following issues were examined:

- Modular type
- Open architecture
- Plug-and-play type systems
- Use of industry standard interfaces
- Integration of component sub-systems relative to public vs. private

The operational environment lent itself to the following issues:

- Physical space
- Terrain
- Urban or rural environment
- Truck route
- Ports of entry to California
- Bridges

Within the site selection category were the following issues:

- Level of institutional partnership between Caltrans and the CHP
- Availability of land/right-of-way
- Proximity to existing operational inspection facility
- Stand-alone locations
- Proximity to and availability of communications and power
- Test area inside a port
- Areas of homeland security concern
- Areas with substantial weight violations

For the data collection process, the following issues were considered:

- Data to be collected
- Purpose of data collection
- Data sharing
- Data security

For the functional requirements and options category the following issues were examined:

- Real-time weighing of a commercial vehicle
- Real-time identification of a commercial vehicle
- Integration of real-time data for screening decisions
- Communication of data to enforcement personnel in real-time
- Real-time identification of the motor carrier responsible for the operation of a CMV
- Implementation of an expanded screening algorithm

- Real-time verification of CMV dimensions
- Availability of data to support resource planning
- Real-time identification of the commercial driver operating the CMV
- Direct enforcement
- Communication of real-time operational data to system managers
- Communication of real-time traveler information to CMV drivers
- Communication of CMV location data to authorized users

For technology requirements and options the following issues were discussed:

- WIM scales
- Camera system
- Screening software
- Communication infrastructure
- Automatic vehicle identification systems
- Over-size detection sensors
- Augmented screening software
- Enhanced communication infrastructure
- Infrared brake screening systems
- CBNR detection sensors

For the stakeholder category, there was an identification of stakeholders and stakeholder champions, and their needs.

For the operational testing and evaluation category the following issues were examined:

- Operational scenarios
- Measures of performance
- Benefits and costs

The final category described was that of the development of a business case.

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CHAPTER 1
INTRODUCTION

This document constitutes the final report for PATH Project Task Order 6105 under contract 65A0208 — "Compliance & Commercial Vehicle Operators: A Systems Evaluation of the Problem & Virtual Solutions". We discuss in this document the concept of Virtual Weigh Stations (VWS), their applicability for California, and how to plan for the implementation of a VWS technology testbed within California.

Current Commercial Motor Vehicle (CMV) screening, inspection, and enforcement activities in California experience significant problems that preclude the State from operating its truck screening and inspection facilities as productively as possible. The fundamental issue at the root of many of the problems is that the number of trucks continues to increase while the number of inspection stations and enforcement capabilities has remained fairly constant over time. Nor have CMV activity practices changed in any significant way. Figure 1 shows for the State the expected increase in daily truck traffic from 1998 to 2020 (Office of Freight Management and Operations, 2006) with the greatest increase in daily truck traffic occurring near urban centers.

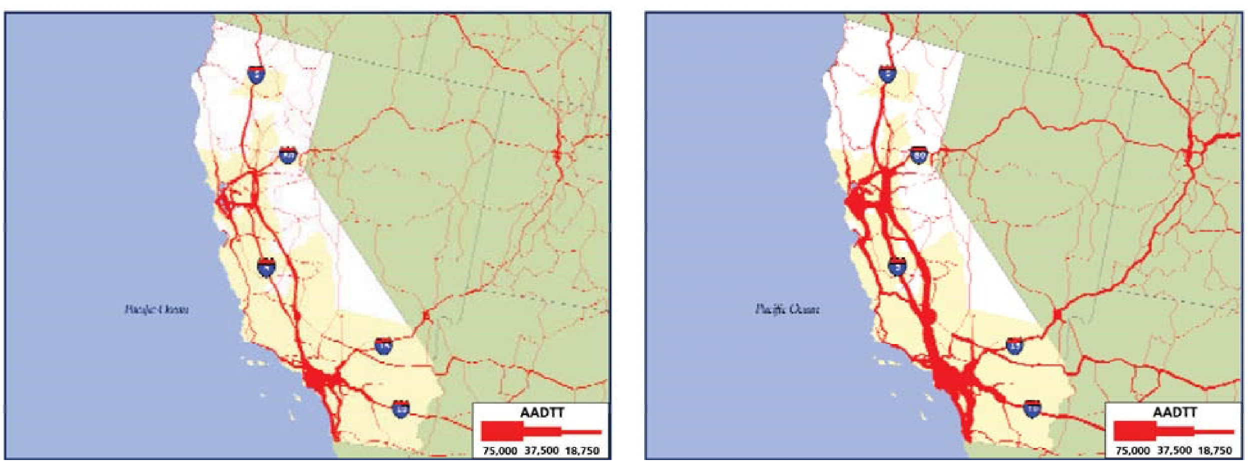

Figure 1: Estimated Average Annual Daily Truck Traffic Growth: 1998-2020

Another example in truck-related growth as measured by the change in truck tonnage between 1998 and 2035 is shown in Table 1. Using 1998 as the baseline year, the numbers in parentheses for years 2020 and 2035 show the percentage growth for that year over 1998 levels, respectively for each truck movement type.

Table 1 Growth in California Truck Weight Shipments (millions of tons)

Year	1998	2020	2035
Within California	906.7	1,570.9 (+73%)	2,179.4 (+140%)
From California	75.7	163.7 (+116%)	366.0 (+383%)
To California	125.2	253.4 (+102%)	518.4 (+314%)

Source: Federal Highway Administration, Office of Operations, Freight Management Operations, http://ops.fhwa.dot.gov/freight/freight_analysis/state_info/california/ca.htm

As a result of this imbalance between the "demand" for inspection and enforcement as represented by the growth in truck traffic and truck volumes over time and the "supply" of inspection and enforcement facilities, the following problems exist:

- If a substantial number of trucks need to be inspected, then queues form at commercial motor vehicle inspection and enforcement facilities that can extend out to the roadways, contributing to
    - Congestion
    - Safety-related hazards
    - Air quality concerns resulting from idling trucks in queue
- If, instead, trucks are allowed to bypass an inspection facility because of limited capacity and/or staff
    - Pavement and structure damage can result contributing to increased roadway reconstruction and resurfacing costs
    - Safety-related hazards
    - Security concerns resulting from unexpected cargo and/or drivers

In response to these problems, the California Department of Transportation (Caltrans) sponsored research to investigate Virtual Weigh Stations (VWS) for commercial vehicles (California PATH Program, et al., 2008). The final phase of this three and a half year research project was initiated in August of 2008 and is documented in this Final Report, which presents the research team's understanding of the key issues that must be considered when planning the development of a commercial motor vehicle Virtual Weigh Station technology testbed. These key issues have been organized into the following categories: system design and architecture, operational environment, siting and location, collection of data, functional and technology requirements, stakeholders, operational testing and evaluation, and business case development. The authors have taken a rather high-level perspective in writing this report: we view it as an initial-stage informational tool that provides a "laundry" or check-off list of VWS technology testbed issues for Caltrans to bear in mind when the appropriate and more favorable time arrives in terms of funding availability to actually deploy such a testbed. At that stage, a detailed implementation plan will need to be developed.

CHAPTER 2
BACKGROUND ON VIRTUAL WEIGH STATIONS IN CALIFORNIA

Consideration of Virtual Weigh Stations in California dates back to approximately 2004 with initial research conducted at the University of California as part of a Caltrans-sponsored project investigating safety and congestion problems on Interstate 710 serving the ports of Los Angeles and Long Beach in Southern California. Such problems were primarily due to the high volume of commercial motor vehicle traffic and the number of overweight vehicles. As part of this research, near term technological solutions were investigated to determine their potential impact on improving safety, congestion, roadway damage, and commercial vehicle enforcement activities. As part of the project research, three aspects of Virtual Weigh Stations were studied:

- Basic concept of Virtual Weigh Stations including key considerations when deploying VWS and recommended strategies for successful implementation of VWS (Regan, A., M. Park, S. Nandiraju, and C.-H. Yang, 2006)
- Estimation of pavement damage and associated costs caused by overweight commercial motor vehicles and potential savings resulting from the implementation of VWS (Santero, N., W. Nokes, and J. Harvey, 2005)
- Legal and institutional barriers to the successful implementation of VWS in the U.S. (Rodier, C., S. Shaheen, and E. Cavanagh, 2006)

In 2005 the METRANS Transportation Center[1] organized and held a one-day workshop to solicit feedback from both Caltrans and the California Highway Patrol (CHP) – the two primary stakeholders in California for VWS deployment – and to have an open discussion of VWS-related issues based on findings from these three research studies (Agarwal, A., 2005). Subsequently Caltrans deployed a prototype virtual weigh station at the Cordelia weigh enforcement facility to display at the 12th Intelligent Transport Systems World Congress held in San Francisco later that year. The Cordelia weigh station is located on eastbound Interstate 80, approximately halfway between Sacramento and San Francisco, at a point of congestion that is

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[1] The **METRANS Transportation Center** is a US DOT University Transportation Center (UTC); it is a joint partnership of the University of Southern California and California State University, Long Beach; http://www.metrans.org/

not easily or cost effectively bypassed by commercial motor vehicles. It is located in the same place as the PrePass[2] transponder reader in advance of the Cordelia commercial vehicle inspection facility. The Cordelia virtual weigh station's in-pavement technical components include a bending plate Weigh-In-Motion (WIM) scale, a vehicle detection system, and a camera triggering system.

Figure 2 shows the VWS prototype that was developed to gather truck identification information using infrastructure-based equipment that monitored truck weights at freeway speeds and provided data to the CHP in a way that allowed it to stop and weigh trucks in areas where fixed inspection stations were neither available nor possible. The wide black strip is the scale with WIM loops flanking the scale on either side of the outside lane. A third loop – the "camera trigger" – is located upstream. Through the collected WIM data, Caltrans has been able to identify areas of overweight violators and document the volume as well as patterns of overweight.

[2] PrePass is an automatic vehicle identification (AVI) system that enables participating transponder-equipped commercial vehicles to be pre-screened throughout the nation at designated weigh stations, port-of-entry facilities and agricultural interdiction facilities. Cleared vehicles are then able to "bypass" the facility while traveling at highway speed, eliminating the need to stop; http://www.prepass.com/

Figure 2 Cordelia Prototype VWS In-Ground Equipment

Figure 3 shows the Cordelia VWS web-browser display. Across the top of the box, vehicle information can be viewed, including identification of lane, FHWA vehicle class and speed, the calculated 18K ESAL[3] number, and gross weight and maximum allowable gross vehicle weight for its class. In the center of the figure the vehicle length and weight by axle is displayed; in the lower right box all normal WIM data is displayed. The table below shows axles in feet and axles measured weight in KIPS[4] and maximum allowable weight in KIPS; the license plate number has been extracted from the photo on the lower left of the box and shows a confidence level number of 932 on a scale from 0 – 999 that the license number is correct. The photo on the left

[3] ESAL = Equivalent Single Axle Load
[4] KIPS = a unit of weight equal to 1,000 pounds (455 kilograms)

shows the front of the truck including the license plate in which the license plate number was extracted using optical character recognition and a license plate reader algorithm. The upper left photo shows the front and the right side of the truck where data is displayed; other four pairs of images show the last four vehicles.

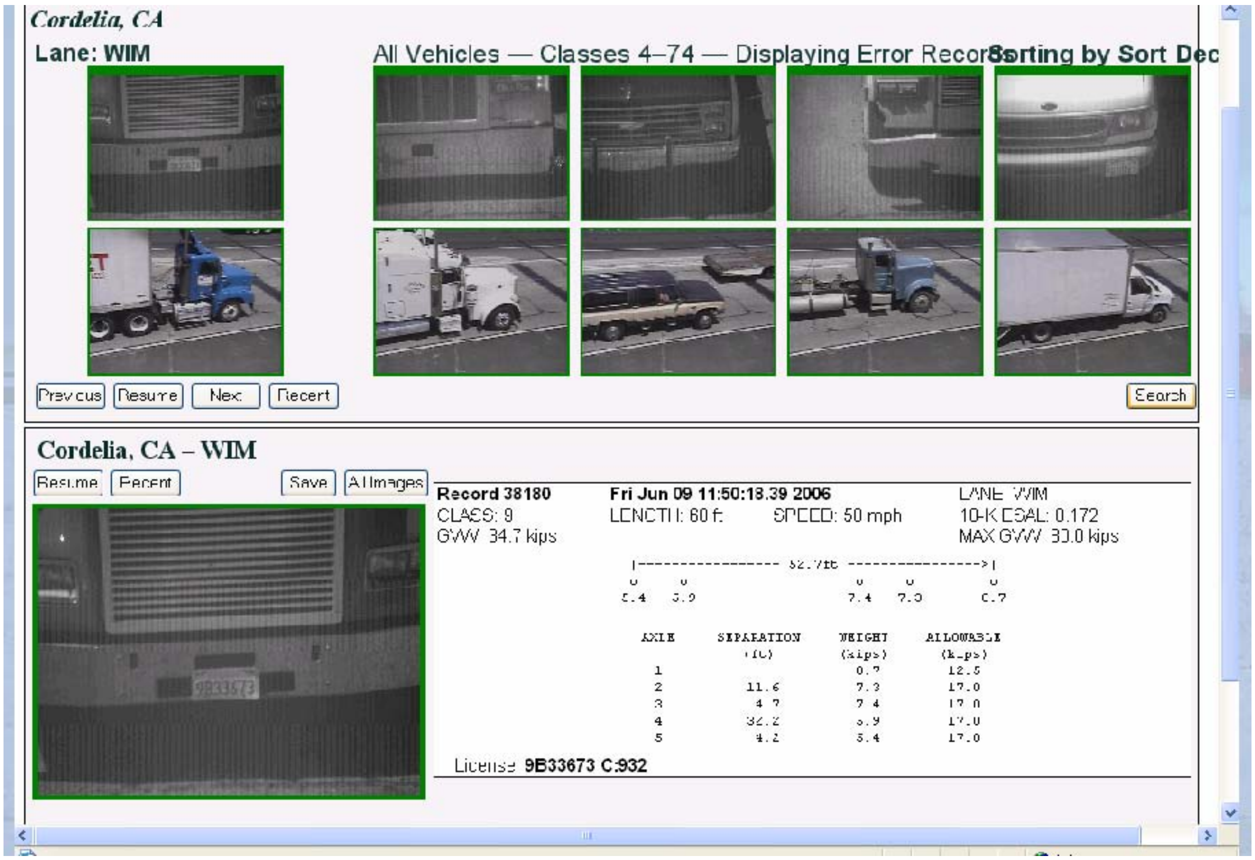

Figure 3 Cordelia Prototype VWS Web-Browser Display

Since 2005, while no additional deployment-related work of VWS systems in California beyond the VWS prototype has been achieved, California has nonetheless been very much involved in two significant activities that have made progress toward further implementation of these systems. First, California was a member of AASHTO's Technology Implementation Group's

(TIG) Lead States Team[5] on Virtual Weigh-In Motion Stations[6], which focused on the implementation of VWS technologies to further AASHTO's mission and stated goals and objectives in particular, "to share information with AASHTO member agencies, local agencies, and their industry partners to improve the Nation's transportation system." (AASHTO, 2006). Representatives from these five states met regularly to champion their respective VWS work producing a VWS brochure[7], presentation material, and a video[8] of their five states' VWS programs. Secondly, Caltrans participated in the FHWA's *Truck Size and Weight Enforcement Technology Project*[9]. The primary project objective was to recommend strategies to encourage the deployment of roadside technologies to improve truck size and weight enforcement in the U.S. This project was completed in June 2009 and documented in a series of individual Task Reports covering the following topics:

- Data sharing with both public and private sectors
- State of the practice of roadside technologies
- Technology deployment challenges and guidelines on the use of WIM in roadside enforcement
- Concept of operations for VWS
- Implementation planning

[5] The other four states included Nevada, Indiana, Florida, and North Dakota.
[6] Virtual weigh-in motion stations is the term used by the TIG; it is synonymous with Virtual Weigh Stations.
[7] American Association of State Highway and Transportation Officials (AASHTO), *Virtual Weigh-In Motion: A "WIM-win" for transportation agencies*, http://www.transportation.org/sites/aashtotig/docs/VWIM%20Brochure%20Final%2010-27-06.pdf, October 2006.
[8] Website address is http://tig.transportation.org/?siteid=57&pageid=1003 and must be used with Internet Explorer browser
[9] The Federal Highway Administration (FHWA) contracted with Cambridge Systematics, Inc. to conduct the Truck Size and Weight Enforcement Technology Project in collaboration with personnel from the Office of Freight Management and Operations, under the guidance of a Technical Review Committee comprising representatives of FHWA, the Federal Motor Carrier Safety Administration (FMCSA), the Intelligent Transportation Systems (ITS) Joint Program Office of the Research and Innovative Technology Administration (RITA), and the Commercial Vehicle Safety Alliance (CVSA).

CHAPTER 3
MOTIVATION FOR ESTABLISHING A VIRTUAL WEIGH STATION TECHNOLOGY TESTBED

The State of California is very much interested in the deployment of Virtual Weigh Stations. In its deployment planning process for VWS within the State, California has thus far sponsored VWS-related academic research studies and deployed a prototype VWS adjacent to the already existing fixed inspection weigh station at the Cordelia commercial vehicle enforcement facility with primarily in-pavement technology. The selection by Caltrans of the Cordelia site as the preferred prototype location was made after consideration of issues associated with Cordelia and a weigh station facility on I-710 in southern California, including

- Whether the prototype VWS should be located in areas not presently covered by WIM stations or static weigh inspection facilities
- Whether the existing weigh inspection facilities should be upgraded in order to deploy a prototype VWS
- Whether the prototype VWS should be located in northern or southern California or both

Siting the prototype VWS at Cordelia also had the advantage of being relatively close to San Francisco, the site of the then upcoming ITS World Congress in November 2005 for which the prototype VWS would be displayed. Cordelia, also being relatively close to Sacramento, was also conveniently located for regular visits by political decision makers and public agency officials. It had extensive infrastructure including a communication system in place, which can significantly reduce the time and cost of building VWS. Again, it had been argued that the Cordelia site would not be a true “virtual” station as it was in fact a “real” static scale weight and inspection facility. If built at Cordelia, it would also be very difficult to correctly estimate the success or failure of VWS. On the other hand, weigh station facilities at Cordelia would make determining ground-truth of the enhanced WIM data possible. Nonetheless, after considering these tradeoffs the Cordelia weigh station was overall deemed to be the preferred prototype VWS location.

California has used a building block approach over time for its VWS deployment process. The next step for California to undertake toward implementation of Virtual Weigh Stations is the development of a technology testbed, which is a platform for experimentation of development projects allowing for rigorous, transparent and replicable testing of new technologies.

The objectives of implementing the technology testbed are to

- Evaluate new and emerging WIM technologies
- Evaluate and analyze calibration needs, frequency and techniques
- Compare technologies, one against another, including Bridge WIM
- Investigate data mining accuracy and calibration, including identification of data patterns that indicate need for calibration, or pending failure
- Evaluate new and emerging communications methods/ technologies
- Evaluate various camera technologies, including License Plate Reader (LPR) and Optical Character Recognition (OCR)
- Evaluate new and emerging sensors to replace loops for WIM
- Evaluate sensors for air quality, Chemical-Nuclear-Biological-Radiological (CNBR) emissions, and hot/cold brakes

CHAPTER 4
SYSTEM DESIGN AND ARCHITECTURE

The design of a successful commercial motor vehicle Virtual Weigh Station technology testbed and its architecture requires a set of criteria to be met or issues to be addressed. In the following we describe and discuss these criteria.

Modular Type

The modularity of the system makes it possible for future components to be easily added to it for upgrades as technology advances. A modular type system can reduce future design, repair, and modification times and therefore cost for each new component.

Open Architecture

The open architecture helps make the system to be not reliant on proprietary or customized systems or to be stove piped in structure. This not only saves money for the system as competing vendors try to provide components at lower prices but also reduces the dependence of the system on any one of the original equipment manufacturers (OEMs). In an unforeseeable event that any OEM goes out of business or decides to stop manufacturing a system component, another manufacturer can step in and manufacture the needed component.

Plug-and-Play Type Systems

If the system is of plug-and-play type, then time may be saved on assembling and testing of the system at different locations.

Use Industry Standard Interfaces

Using standard interfaces is important to ensure that all the components can work together. The hardware and software should seamlessly and efficiently work together. Though the hardware interfaces between system components are easily recognizable, software interfaces can be more challenging. If one component works with only one operating system and not others, then a new software driver needs to be produced, which could be costly.

Integration of Components Sub-Systems: Public vs. Private

There is also an issue regarding the integrator and whether it would be entirely from the public sector or private sector. The advantages of having a public sector system integrator would be the lack of custom 'fixes' and contractual agreements. The advantage of having the private sector would be the extra 'step up' in technology provided by a company and the know-how needed to install new technologies especially in the context of multiple sub-systems needing to work together as a single unit. A public/private partnership may actually work best to begin with and then transition to be a purely publicly operated facility.

CHAPTER 5
OPERATIONAL ENVIRONMENT

Consideration must be given to the operational environment of a commercial motor vehicle Virtual Weigh Station technology testbed in order for it to be successfully implemented. Below is a description of numerous components of a testbed's operational environment.

Physical Space

The system requires a physical space where the system and the operator(s) are safely housed. The size of this structure depends on a variety of factors including the size of system components and equipment.

Terrain

Terrain is important when a site for a VWS technology testbed is being selected as different terrain offer different opportunities or challenges for the testbed. If the testbed is working in a difficult terrain such as in a mountainous area, then it could become a more valuable alternative to existing weigh-in-motion (WIM) stations. If trucks can be processed faster on an uphill VWS than in a traditional WIM station, it helps them to return easier to the mainline or even stay in the mainline depending on the system design. Special attention must be given to the field of views of antennas and radars in challenging and uneven terrain where a clear line of sight is desired or possibly required.

Typical Weather Conditions – Adequate Location for Drainage

Typical weather conditions in the operational environment should be considered, especially during the winter season and its inclement weather, and the need for adequate water drainage to keep buildings that house offices and equipment dry and free from flooding and possible damage.

Urban or Rural Environment

An urban environment for a VWS testbed may impose air quality constraints whereas a rural environment offers possibility of a remote site.

Truck Route

There are trucks on every single road in California but to evaluate the success of a VWS testbed, it is best to select a location that is on an established truck route and frequented by many trucks during all times of day and night.

Port of Entry (POE) to California

One possible location for implementation of a VWS technology testbed is near a port of entry to California. The POEs to California are seaports, border points with Mexico, and border points with neighboring states of Arizona, Nevada, and Oregon. One goal of Caltrans and the CHP is to have a WIM at all of these locations with exceptions made for some minor roads that connect California with neighboring states. Near all of these points, there usually exists a significant amount of commercial motor vehicle activity, which would provide ample observational data for evaluation of the testbed.

Bridges

There are two types of bridge-related systems that can be considered for siting a VWS adjacent to a bridge: *Bridge WIMs* and a *bridge application of a WIM*. A bridge weigh-in-motion system (B-WIM) is an existing bridge used as a WIM system. The resulting collected data can be used for any WIM application such as pre-selection of overweight trucks for static weighing, pavement design/assessment or bridge design/assessment. A B-WIM is actually a process by which axle and gross vehicle weights of trucks traveling at highway speeds can be determined from instrumented bridges. B-WIM systems involve attaching strain transducers to the undersurface of a bridge structure (Figure 4) and placing sensors for detecting axles in order to provide information on vehicle velocity, axle spacings and position of each vehicle. As the measurements are performed through the period in which the whole vehicle is passing over the structure, the system is less influenced by dynamic effects. Bridge WIM systems also provide information about impact, lateral distribution, and strain records which are used for further bridge analysis.

In a bridge application of a WIM, WIM data can be collected using any WIM technology such as bending plate or strip sensors or bridge WIM. The resulting traffic data is being used for the assessment of loading on bridges. Nevertheless, if a B-WIM system is installed on a bridge, which is assessed, it can provide additional useful information about the behavior of the structure (influence lines, Dynamic Amplification Factor, distribution of loads, strain records etc.).

In Europe, extensive research was under way in the late 1990's as a part of the WAVE[10] project. Work on further development of B-WIM has focused primarily on increasing the accuracy for typical bridges, extension of B-WIM to various types of bridges, on dynamic analysis of typical bridges and on calibration procedures. Today Bridge-WIMs due to their unique features are regaining popularity and are a well established WIM technology that is used in many European countries, in India and in Canada. Their main advantages are:

- Full portability: all equipment can be detached from one site and be installed on another site in a few hours
- High accuracy of results: long weighing platform (entire length of the bridge) proves beneficial in dealing with dynamic vehicle loading, quick installation and maintenance as there is no need for stopping the traffic and no direct contact with pavement, price efficiency.

[10] **W**eighing in motion of **A**xles and **V**ehicles for **E**urope

Figure 4 Strain Transducer to Underside of Bridge Structure

CHAPTER 6
SITING AND LOCATION

Site Selection

A number of factors are necessary to consider for the site selection process for a successful VWS testbed. The following discussion lists and describes these factors.

Level of Institutional Partnership Between Caltrans and the CHP

The cooperation and sense of partnership between Caltrans and CHP is not only important in the selection of a suitable site for a VWS technology testbed but also for giving the testbed the best opportunity for success. Without a strong Caltrans/CHP partnership, this concept would likely be unsuccessful. If Headquarters and local Caltrans districts and CHP staff are not only on board with the project but truly championing the project, the project will likely fail. To some degree local Caltrans and CHP staff carry more weight and are even more important than headquarters since they have to operate and maintain this new system and so are closer to the system.

Availability of Land / Right-Of-Way

If the plan for a VWS testbed calls for it to be located in a brand new facility, then the selected site should be either on Caltrans right-of-way or have a land owner that is willing to sell his/her land to Caltrans. The availability of funding and project timelines should be considered for this factor. It should be noted that in many parts of California Caltrans owns at least 30 feet from the edge-of-roadway on each side of its freeways. In some cases the right-of-way is much more than 30 feet especially in rural and remote areas.

Proximity to Existing Operational Inspection Facility

If the selected testbed site is close to an existing inspection facility, e.g., ongoing I80/SR12 Interchange project at Cordelia Station, then it offers an opportunity to use the existing facility as ground truth for evaluation. If this type of site is selected, then a very careful approach must be taken to make sure that intermingling and integration issues do not adversely affect the traffic flow on one hand and render the data collected unreliable and inaccurate on the other hand.

Stand-Alone Locations

Stand-alone locations could be either 1) a new facility, 2) an existing facility where the station is completely transformed to a VWS or 3) a part of an existing facility designed as a VWS. The new facility offers a "starting from scratch" option and the opportunity to avoid potential integration and intermingling issues, both technical and institutional, associated with siting at an existing facility. From a realistic funding and cost perspective, it may not be feasible to have a brand new facility for a VWS testbed. It will likely be located in an existing facility but stand-alone locations should at least be carefully considered.

Proximity to and Availability of Communications and Power-related Equipment

The proximity and availability of communications including the telephone demarcation boxes and cellular coverage should be investigated prior to site selection. The same should be done for power. Bringing communications and power to any selected site would constitute a major cost to the project.

Test Area Inside a Port

Installing a VWS testbed inside a port near its exit gate, e.g. Long Beach Seaport, can offer some benefits and needs to be considered. These benefits include ease of access to communications and power, an abundance of commercial motor vehicles, no disruption of freeway traffic flow, possible time savings for trucks, and a more controlled environment for system evaluation. The drawback is the challenge to find a suitable port whose owners and operators are willing to participate in this effort. Also, since it is not on any freeway, the full benefits of traffic flow improvements and pollution reductions cannot easily be evaluated.

Areas of Homeland Security Concern

Prior to September 11, 2001, security relative to commercial vehicle operations played an important role, however, its focus was more on vandalism and the theft of trucks and/or its cargo, as well as interdicting the transport of illicit cargo and contraband. After this date, however, the general security concern for commercial vehicle operations switched almost immediately to the use of stolen trucks and cargo with the intent of carrying out a terrorist act especially using weapons of mass destruction. Security measures implemented after September 11, 2001 reflect the changes in perception indicating that threats of terrorism have become the top priority security risk to the trucking industry. Thus areas of homeland security concern have increased in importance and should be identified and considered. VWS could have the following homeland security applications:

- Load examination from above
- Scanning for CNBR
- Scanning for hazardous materials
- Scanning for license plate/US DOT number

Areas with Substantial Weight Violations

The volume of known commercial motor vehicle weight violations in an area is a factor that should be considered as areas with substantial weight violations would be an attractive location for a VWS testbed because of the plentiful availability of data.

CHAPTER 7
DATA COLLECTION

A number of factors are necessary to consider for the data collection process for a VWS testbed. The following discussion describes these factors including the data to be collected, the use of the data, data storage, sharing of the data, and data security.

Data to be Collected

The types of data that would be collected as part of the functioning of a virtual weigh station technology testbed include the following:

- WIM data (vehicle weight)
- Camera systems data (vehicle photo)
- Safety data
- AVI data (vehicle ID: US DOT number, license plate number)
- Oversize detection systems data (vehicle height, width, length)
- Date/Time/Location stamp data
- Weather data
- AVC data
- Vehicle performance data (current status of on-board equipment, current environmental conditions)
- Motor carrier compliance data

Purpose of Data Collection

Data will be collected for various purposes including the following:

- Planning
    - Data on the movement of commercial motor vehicles can be used to identify major trucking corridors and input to travel demand models
- Screening decision-making and enforcement

    - Data will be integrated with data information systems (commercial vehicle safety and credentialing data repositories[11], safety screening algorithms, and stolen vehicle target lists) to help make screening decisions
- Research
    - Commercial motor vehicle-related research topics, such as pavement/structure studies and safety studies, will require data collected by means of the VWS technology testbed
- Traffic management
    - Real time operational data can be sent to system managers in support of traffic/congestion monitoring and development of travel advisories

Data Storage and Retrieval

The data will be stored in a relational database instance and managed (created, modified, deleted) through a database management application.

Data Sharing and Networking

Data can be shared with authorized users in order to maintain and enhance

- Motor carrier safety
- Operational efficiency
- Freight mobility
- Air quality
- Motor carrier security

Data sharing and networking between stakeholders need to account for data privacy concerns; a data privacy policy would need to be developed if not already established.

Data Security

Actions need to be taken to insure that data is protected from hackers and others who could compromise its security and protection.

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[11] For example, State Commercial Vehicle Information Exchange Window (CVIEW) and national Safety and Fitness Electronic Records (SAFER) will be used to determine carrier's safety performance and credentials history.

CHAPTER 8
FUNCTIONAL REQUIREMENTS AND OPTIONS

Virtual weigh stations can be designed and implemented to support a wide variety of roadside inspection, screening, and enforcement functions. Each function listed in this chapter is taken from what was originally developed and compiled as part of the FHWA-sponsored project *Truck Size and Weight Enforcement Technology Project*. The project contractor, Cambridge Systematics, Inc., organized these functions into three categories: minimum (required), expanded (optional), and future use that could be supported by a VWS, the latter two classes of which were based on stakeholder interviews and discussions[12] conducted by the contractor during the project (Cambridge Systematics, Inc., 2009a). We include each of them here in this chapter to offer the reader the opportunity to consider their relevance to the interests of California as part of its planning for a VWS technology testbed.

Minimum Set / Required VWS Functionality

- <u>Real-time Weighing of a Commercial Vehicle</u> **–** Determine a commercial motor vehicle's approximate axle weights as the vehicle moves across sensors, and calculate the gross vehicle weight and classification based on the number of axles, as well as axle weights and spacings

- <u>Real-time Identification of a Commercial Vehicle</u> **–** Identify all commercial motor vehicles that pass the site

- <u>Integration of Real-Time Data for Screening Decisions</u> **–** Integrate commercial motor vehicle identification and weight data in real-time/near real-time, to support manual (i.e., decisions made by roadside enforcement personnel) or automated (i.e., decisions calculated by the system and then forwarded to a human) targeting of specific commercial vehicles for further enforcement action

[12] California participated in this project as a State stakeholder.

- Communication of Data to Enforcement Personnel in Real-Time – Communicate VWS data (e.g., vehicle photo, weight data) to authorized users (e.g., mobile enforcement personnel stationed downstream from the VWS, enforcement personnel stationed at a fixed inspection site that could be dispatched to intercept an overweight vehicle) in a timely and secure manner.

Expanded / Optional Functionality:

- Real-time Identification of the Motor Carrier Responsible for the Operations of a Commercial Motor Vehicle – Identify the motor carrier that is responsible for the safe operation of the vehicle

- Implementation of an Expanded Screening Algorithm – Integrate additional criteria (e.g., motor carrier history of safety performance and compliance with size and weight standards, current commercial vehicle credential status, current motor carrier credential/operating authority status, driver's license status) into the screening decision

- Real-time Verification of Commercial Motor Vehicle Dimensions – Integrate additional sensors to determine if a commercial vehicle exceeds legal height, width, and length regulations and therefore would require an oversize/overweight permit

- Availability of Data to Support Resource Planning – Provide commercial vehicle average daily trip data (e.g., volume, weight, vehicle classification) to support the scheduling of mobile enforcement activities, and to identify locations in need of fixed enforcement facilities

Future Functionality Supportable by VWS:

- Real-time Identification of the Commercial Driver Operating a Commercial Vehicle and inclusion of Driver Information in the Screening Decision – Identify the individual driving a commercial motor vehicle and determine if that individual can legally operate the vehicle at that time (i.e., commercial driver's license is not revoked or suspended);

- Direct Enforcement – Write a citation or take other enforcement action (e.g., prevent a commercial vehicle from being started) based on data from a VWS;

- Communication of Real-Time Operational Data to System Managers – Serve as a means for onboard vehicle data (e.g., speed, windshield wipers on/off, air temperature) to be transmitted to transportation management centers in support of congestion monitoring and development of travel advisories

- Communication of Real-Time Traveler Information to Commercial Motor Vehicle Drivers – Serve as a means that real-time traffic (e.g., incident warning, congestion, weather advisories) and truck parking (e.g., location, availability) information could be delivered to commercial vehicle drivers operating within a specific geographic area/corridor

- Communication of Commercial Vehicle Location Data to Authorized Users – Accurately capture vehicle location data (i.e., date and time that it passed a VWS) to support private and public sector applications.

CHAPTER 9
TECHNOLOGY REQUIREMENTS AND OPTIONS

The virtual weigh station concept is very flexible and adaptable. As was the case in Chapter 8 on Functional Requirements and Options, each technology described in this chapter is based on what was originally identified in the FHWA-sponsored project *Truck Size and Weight Enforcement Technology Project* and organized into two categories: minimum (required) and optional (at the discretion of each individual State) (Cambridge Systematics, Inc., 2009a). Again, we include them in this chapter to offer the reader the opportunity to consider their relevance to the interests of California. That is, California can customize its VWS deployments to meet its 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)
- Communication Infrastructure (e.g., presence of communication infrastructure at site, presence of power at site).

Minimum Set / Required VWS Technology

At a minimum, the following technologies must be included in the deployment of a virtual weigh station:

- WIM Scales – Determine the approximate axle weights as a vehicle moves across sensors and calculates the gross vehicle weight and classification based on the number of axles, as well as axle weights and spacings
- Camera System **–** Captures real-time images of a commercial vehicle crossing the WIM
- Screening Software **–** Integrates the data from the WIM and camera systems
- Communication Infrastructure **–** Makes the VWS data (e.g., vehicle photo, weight data) available to authorized users (e.g., mobile enforcement personnel stationed “downstream” from the VWS, enforcement personnel stationed at a fixed inspection site that could be dispatched to intercept an overweight vehicle) in a timely and secure manner. The VWS allows for the use of a variety of communication technologies. Depending on what is

available at the site, authorized personnel may use a wireless or a wired connection to a secure Internet site to access the information.

Optional Technology:

At the discretion of California, a virtual weigh station also may include one or more of the following optional technologies:

- Automatic Vehicle Identification (AVI) **–** Use a variety of roadside technologies to identify a moving commercial vehicle. These systems remove the need for visual (human) recognition of a commercial motor vehicle and allow an automated screening decision to be made. The most commonly deployed AVI technologies at virtual weigh station sites are license plate readers (LPR) or United States Department of Transportation (USDOT) number readers that use a camera system augmented with optical character recognition (OCR) software. These forms of AVI capture an image of a commercial motor vehicle's license plate or USDOT number and then use OCR software to translate the photographic image into a value that can be stored and/or used by the screening software as the basis to query other information systems (e.g., state Commercial Vehicle Information Exchange Window[13]). Another commonly used AVI technology within the commercial vehicle regulatory arena is a windshield-mounted transponder. Transponders form the basis for AVI at fixed sites but have not been widely deployed as part of VWS, due to their limited market penetration and the desire of system operators to be able to screen all commercial vehicles at a VWS — not just those with transponders;
- Over-Size Detection Sensors **–** Use a variety of technologies (e.g., infrared, laser) to determine if a commercial motor vehicle exceeds the legal size restrictions (height, width, length) on a particular roadway;
- Augmented Screening Software **–** Integrates the data from the WIM, AVI, other roadside sensors (e.g., over-height detection system), and safety data information systems (e.g.,

[13] A Commercial Vehicle Information Exchange Window (CVIEW) is a State data repository and/or exchange mechanism deployed as part of the Commercial Vehicle Information Systems and Networks (CVISN) system. A State's CVIEW typically stores information regarding commercial vehicle credentials (e.g., status of vehicle registration, status of fuel tax payments, presence of an oversize/overweight [OS/OW] permit), as well as commercial vehicle safety information (e.g., ISS-D score, out-of-service [OOS] orders, results from past vehicle inspections). The CVIEW may be a physical database deployed by the State or a series of data sharing protocols that retrieves data from their respective legacy systems in real-time upon demand.

commercial motor vehicle safety databases) to assist making a screening decision. The augmented screening software uses the vehicle identifiers generated by the AVI technology to query the safety data information systems in real-time.

- Enhanced Communication Infrastructur**e** **–** Communicates the automated screening decision to authorized users (e.g., enforcement personnel, commercial driver) possibly even using variable message signs in their VWS deployments to convey the screening decision to the commercial vehicle driver.

- Infrared Brake Screening Systems **–** Infrared imaging to screen commercial motor vehicles (i.e., large trucks and buses) for subsequent inspection. The technology detects malfunctioning brakes and other problems such as flat tires. The InfraRed Inspection System (IRISystem) was evaluated in a field study to determine the effectiveness of this new technology for enhancing the screening of commercial motor vehicles (CMVs) for subsequent inspection. The Infrared Inspection System (IRISystem) is a minivan equipped with an infrared camera on the roof and a display screen inside the vehicle. Enforcement personnel tested its effectiveness at roadside inspection facilities by screening for brake defects and producing results in a matter of seconds, known as "real time." As a commercial motor vehicle decelerates to enter a roadside inspection facility, an IRISystem operator scans the wheels with the camera. A thermal image of the wheels, showing their relative temperature, is displayed on the screen inside the van. Because the application of brakes creates heat, the wheels with functional (warm) brakes appear bright white in the infrared image, while the wheels with inoperative (cold) brakes appear dark. A color image enables the operator to easily identify a vehicle with functional or inoperative brakes.

- CNBR Detection Sensors **–** Technological systems either planned for or implemented in the immediate aftermath of the September 11, 2001 terrorist attacks include cargo detection of chemical, nuclear, biological, and radiological type material and/or weapons that are inside a container or cargo hold. Such technologies can be non-intrusive inspection systems, e.g., x-ray, gamma ray, or neutron rays. Moreover, such systems do not necessarily refer to a single particular technology that can detect all four types of WMD material, nor is there any known single piece of equipment that can check all four types of material.

CHAPTER 10
IDENTIFICATION OF STAKEHOLDERS

Identification of Stakeholders

Stakeholders include organizations – public or private – or individuals who

- Directly generate benefits realized by other stakeholders, for example, by means of data sharing or information exchange
- Have an interest in the short and long term success of the program in question
- Contribute to or are affected by some part of the program or initiative
- Can influence the real or perceived success of the program

Virtual weigh station stakeholders include State Department of Transportation, State and local enforcement agencies, other State agencies, Federal agencies, motor carriers, technology manufacturers and vendors, highway and commercial vehicle safety organizations, and the driving public.

For California, stakeholders include two primary organizations: California Department of Transportation (Caltrans) and the California Highway Patrol (CHP). Caltrans is the owner and maintainer agency for commercial vehicle inspection, screening, and enforcement facilities. The CHP is the operator agency for CVEFs. Other State agency stakeholders include:

- Board of Equalization (BoE)
- Air Resources Board (ARB)
- Department of Motor Vehicles (DMV)
- Department of Food and Agriculture (DFA)
- Public Utilities Commission (PUC)

The BoE collects California state sales and use tax, as well as fuel, alcohol, and tobacco taxes and fees that provide revenue for state government and funding for counties, cities, and special districts. The BoE is also a regulatory agency that requires fuel permits or licenses for dieselpowered vehicles used in interstate commerce, which has two axles and a gross vehicle weight or registered gross vehicle weight exceeding 26,000 pounds (11,797 kilograms), or has three or more axles regardless of weight. The ARB regulates commercial vehicle emissions.

There are two state agencies that have regulatory authority over the trucking industry in each state the Public Utilities Commission and the Department of Motor Vehicles. The DMV is in charge of vehicle registration and driver licensing as well as intrastate requirements for maintaining commercial vehicle log books to record hours of service. The Tariff and License branch in the transportation division of the PUC regulates intrastate trucking. Intrastate trucking refers to freight shipments commencing and concluding within the state. Highway common carriers operating within the boundaries of one state (intrastate trucking) are required to have PUC operating authority or a trip permit (bingo stamps) to carry freight within the state. The registered owner must also file proof of insurance (certificate of insurance) with the PUC. The PUC issues operating permits and sets minimum and maximum intrastate freight rates. The PUC requires trucking firms, depending on the size of the annual gross receipts, to file quarterly and/or annual reports.

Relevant federal agency stakeholders include the following:

- Federal Motor Carrier Safety Administration (FMCSA)
- Department of Homeland Security (DHS)
- Environmental Protection Agency (EPA)
- Internal Revenue Service (IRS)
- Department of Defense (DOD)
- US Department of Agriculture (USDA)

Stakeholder Needs

Based on work performed as part of the FHWA-sponsored project *Truck Size and Weight Enforcement Technology Project*, the project contractor, Cambridge Systematics, Inc., compiled the following list of stakeholder needs for virtual weigh stations (Cambridge Systematics, Inc., 2009a):

All stakeholders have the following high-level needs with respect to virtual weigh stations:

- Safety
    - Reduce the number of highway fatalities and injuries
    - Reduce the number of commercial motor vehicle crashes
- Mobility
    - Reduce congestion and delay on highways
- Air Quality and Fuel Consumption
    - Reduce commercial motor vehicle fuel consumption
    - Reduce commercial motor vehicle pollutant emissions and improve air quality
- Road/Bridge Infrastructure
    - Reduce roadway damage and preserve highway infrastructure
- Productivity
    - Decrease transportation costs for freight

Public agency stakeholders have the following additional needs

- Improve the efficiency and effectiveness of roadside enforcement operations
- Improve commercial motor vehicle compliance with Federal and California truck size and weight regulations
- Reduce infrastructure and enforcement costs
- Provide data for traffic monitoring, pavement monitoring, and resource planning

Commercial motor vehicle carriers have the following specific needs

- Improve the reliability of scheduling highway-based freight deliveries
- Improve the efficiency of trips
- Increase productivity
- Level the playing field for safe and legal carriers
- Improve confidence levels in meeting transport contracting requirements
- Enhance company monitoring of driver performance and compliance
- Enhance vehicle fleet tracking and goods tracking capabilities

Identification of Champions

The following discussion of stakeholder champions is again based on work performed by Cambridge Systematics, Inc. as part of the federally-sponsored *Truck Size and Weight Enforcement Technology Project* (Cambridge Systematics, Inc., 2009b).

A champion is a special stakeholder who is effective at promoting a program including communicating its benefits to all stakeholders and addressing its challenges; a champion is a necessary component for a successful program. Making change can be difficult and States may find that inertia on the part of particular stakeholders can place barriers in the way of the deployment of new technologies. With respect to roadside technologies, inertia may come from the State's enforcement agency or from the State's transportation agency that are resistant to moving from traditional practices such as weigh stations to virtual weigh stations. Under such conditions, a champion (or champions) can provide the focused leadership that can make the difference and progress toward new technology deployments.

It is likely that the champion will emerge from the agency that has the most to gain from the deployment of the new system technologies, that is, VWS. This provides an incentive to work hard to implement the technologies.

CHAPTER 11
OPERATIONAL TESTING AND EVALUATION

A number of factors are necessary to consider for a successful VWS testbed under the operational testing and evaluation phase. The following discussion lists and describes these factors.

Operational Scenarios

It is desirable for the selected testbed site to have a range of different traffic, weather, and other conditions that would be used for the complete evaluation of the system. The following are examples of such multiple operational scenarios.

Various Commercial Truck Volumes

Since commercial trucks are the main concerns for this testbed, it will be desirable to evaluate the usefulness and efficiency of the system under various truck/non-truck traffic volume combinations. The volume of trucks in any given traffic conditions especially near saturation state will be a big determinant of how smoothly and at what speed the traffic flow is moving. Research has shown that even a relatively small percentage of trucks can have an adverse affect the traffic flow. If the VWS testbed is indeed designed in a way that trucks remain in the mainline with the same traveling speed as before, then this can help with the traffic flow. The exiting and entering trucks from the scale facility ramps would disrupt the traffic flow and reduce the efficiency of the system. If indeed VWS can be proven to help smooth out the traffic flow, then the results will also show a net reduction in pollution and travel time for the system as a whole. Since many commercial trucks travel at night, it is possible to get a higher percentage of trucks as the total volume of vehicles at night, but in this particular case the entering and exiting trucks would have less impact on the performance of the freeway system.

Inclement Weather Conditions

The performance of VWS should also be evaluated in inclement weather conditions. The first objective is to make sure that all of the system components still perform as reliably as they do under good weather conditions. The second objective is to evaluate and analyze whether VWS has an operational advantage or disadvantage over traditional WIM stations in inclement weather. This evaluation is particularly important since California is a very large state with places that experience large amounts of wind, rain, and snow in winter time and very high temperatures in summer time.

Various Speed Conditions

Another desirable factor for evaluation of this testbed is to determine whether VWS is capable to perform all of its intended functions for up to what is the maximum truck speed. If this maximum speed is less than the prevailing speed at free flow conditions, then it requires the trucks to slow down for VWS. This would have an adverse effect on system efficiency. At the other extreme, if VWS is not capable of performing all of its functions in stop-and-go conditions, then the overall usefulness and reliability of VWS would be greatly reduced.

Measures of Performance

The performance measures that should be considered may be organized into the following categories:

- Technology Performance
- User Satisfaction
- Human Factors
- Level of Cross-Agency Coordination

Technology Performance

Under Technology Performance there are several individual measures that need to be considered:

- Accuracy
- Precision
- Reliability
- Data latency
- System maintainability

Human Factors

Under Human Factors the following individual measures need to be considered:

- Staff expertise and training
- Working conditions
- Human machine interface

The working conditions may contribute to or hinder the staff's ability to do his/her job effectively and could be divided into numerous categories including working environment, visual display of the computer screen, computer keyboard, and furniture. The working environment grouping may include attributes such as illumination, noise levels, and thermal characteristics (heating and cooling). The keyboard category may include attributes such as height, slope, key force, and stability. Furniture considers primarily the work surface and seating characteristics (height, depth, backrest, arm rest, and casters).

Benefits and Costs

While no formal evaluation of VWS has been completed, anecdotal information and evaluation results from deployments of similar roadside applications provide examples of the wide range of benefits that can potentially occur as a result of implementing VWS (Cambridge Systematics, Inc., 2009a):

- <u>Increased Protection and Preservation of California's Roadway Infrastructure</u> **—** Overweight trucks are estimated to cause hundreds of millions of dollars in damage to the nation's roadways each year. Virtual weigh stations have the potential to dramatically reduce the damage done to the roadways by overweight vehicles operating illegally by expanding the geographic scope of the nation's truck size and weight enforcement programs and deploying enforcement assets into areas currently not monitored by fixed or mobile enforcement resources. Virtual weigh stations also may increase overall compliance with size and weight regulations because commercial vehicles may be unable to avoid enforcement resources as easily in the future and their operators will therefore be more willing to comply.
- <u>Increased Efficiency of Enforcement Assets</u> **—** Enforcement personnel continue to be inundated by the number of commercial motor vehicles operating in the U.S. and the volume of trips made by these vehicles. Between 1990 and 2006 vehicle miles traveled by large

trucks increased by 53 percent and the number of large trucks registered in the U.S. increased by 42 percent[14]. The sizeable increase in the number and volume of commercial vehicles to be regulated occurred without a corresponding increase in enforcement personnel. Virtual weigh stations have the potential to address this issue by extending a State's enforcement program to bypass and secondary routes and focusing its limited human enforcement assets on commercial vehicles that are known to be overweight or have other increased risk factors (e.g., operated by a carrier with a poor history of safety performance). This improved efficiency of enforcement personnel also will benefit legally operating commercial vehicle operators because it will serve to "level the playing field" and ensure that some operators are not deriving an unfair competitive advantage by operating illegally.

- <u>Improved Highway Safety</u> — The recently completed National Evaluation of the Commercial Vehicle Information Systems and Networks (CVISN) program included an in-depth analysis of the safety benefits that could be derived from the increased use of roadside enforcement technologies and the increased targeting of commercial vehicle operators with histories of poor safety performance. This analysis revealed that the nationwide deployment of roadside technologies could result in fewer fatal crashes and fatalities than if the inspection selection process was based solely on manual (human) screening[15]. Expanding the number of technology-equipped sites through the deployment of virtual weigh stations with expanded functionality should directly support these safety results.
- <u>Improved Operations Time</u> — As part of the national CVISN evaluation, electronic screening functions – similar to certain VWS functions – were determined to have contributed to motor carriers experiencing reduced delays[16]. Based on the similarity of the VWS and electronic screening concepts, a similar percentage of motor carriers interacting with VWS likely will derive operational benefits from this technology.
- <u>Improved Freight Data for Planning</u> — Having access to accurate data regarding the movement of commercial vehicles across the transportation system is a key component of effective and accurate transportation planning, especially freight planning. These data are used to identify corridors that support commercial vehicle traffic, as well as to provide inputs

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[14] *Large Truck Crash Facts 2006*, Federal Motor Carrier Safety Administration, January 2008, page 4.
[15] *CVISN National Evaluation Report*, Volume 1, Federal Motor Carrier Safety Administration, pages 7-13.
[16] *CVISN National Evaluation Report*, Volume 1, Federal Motor Carrier Safety Administration, pages 5-13.

to travel demand models that forecast the impact of a change to a region's infrastructure. Virtual weigh stations have the potential to generate and provide such data to planners.

- Improved Air Quality — A primary operational characteristic of VWS is that commercial motor vehicles known to be operating within legal weight limits will be allowed to proceed at highway speeds without being required to stop for roadside inspection. The targeting of non-compliant commercial vehicles decreases the number of commercial motor vehicles that are stopped for roadside inspections. The decrease in stopped and idling commercial vehicles has the potential to reduce pollutant emissions and improve air quality.

There are numerous cost-related individual performance measures that should be considered during the operational testing and evaluation phase, as follows:

- Land / right-of-way acquisition
- System design and integration
- Procurement of hardware & software
- Selection of communication methods (wired connection, wireless)
- Installation (e.g., infrastructure improvements such as new concrete, grinding, trenching, etc.)
- Operations & Maintenance (e.g., power, physically maintain sensors)

VWS is a low cost alternative to expanding a State's truck size and weight enforcement program. Recent VWS deployments have cost between $300,000 and $1,400,000,[17] as compared to building a new fixed weigh station, which could cost as much as $300 million if land acquisition is required. In addition to the lower cost, virtual weigh stations offer increased operational flexibility and are specifically designed to address some of the inherent weaknesses of fixed operations (e.g., easily bypassed, limited hours of operation).

[17] Data is from State applications for Federal CVISN Deployment grant applications, Fiscal Years 2006-2008.

CHAPTER 12
BUSINESS CASE DEVELOPMENT

In order to help ensure a successful deployment of a virtual weigh station technology testbed in California, it is recommended that a business case be developed to guide its deployment. A business case would enable California to obtain "management commitment and approval for investments in technologies and provides a framework for planning and managing the changes that will likely occur when new technologies are introduced." (Cambridge Systematics, Inc., 2009b).

California's business case for VWS technology deployments should be based on its particular environment and needs. A typical business case includes a description of the following factors:

- Needs
- Problems and proposed alternative solutions
- Assumptions and constraints
- Benefits and costs

For deployment of roadside virtual weigh stations, the following questions should be answered and be part of the business case:

- Where on the highway system do problems such as weight, size, safety, exist?
- What technologies are available by means of development or procurement to address such problems?
- What resources are available in California to apply to the problems including but necessarily limited to human, existing technologies, access to Federal grants?
- What other agencies or organizations in California have a potential interest in solving the identified problems?
- What issues and/or obstacles have to be addressed in order to make progress, such as lack of staff with necessary expertise or lack of sufficient funding?

- How can California obtain the best return on its investment in a technology deployment of a Virtual Weigh Station?

The business case may reflect the adoption of new or modified enforcement strategies that support non-traditional enforcement operations in order to alleviate the high costs of weigh station construction and attendant staffing power requirements.

CHAPTER 13
CONCLUSIONS

For the last five years California has investigated different aspects of Virtual Weigh Stations ranging from academic studies including a cost-effectiveness analysis, legal and institutional barriers to their successful implementation, and strategies for successful implementation to a prototype deployment of a VWS at the Cordelia commercial motor vehicle enforcement facility in Northern California. At this stage in its building block deployment planning approach, the State is interested in implementing a VWS technology testbed; however, current lack of guaranteed funding availability for such an enterprise remains a significant issue and has precluded detailed implementation planning from moving forward at this time. Nonetheless, having such a testbed continues to be an important objective on the deployment horizon for the State and toward that end, a high-level description of the issues has been developed in this report and serves as an initial-stage informational tool that provides a check-off list of VWS technology testbed issues for Caltrans to consider now as well as when the more appropriate time arrives to actually implement such a testbed.

These issues were organized into the following categories: system design and architecture, operational environment, siting and location, data collection, functional requirements and options, technology requirements and options, identification of stakeholders, operational testing and evaluation (operational scenarios, performance measures, benefits & costs), and business case development.

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