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Interim Report: Compliance and Commercial Vehicle Operators – A Systems Evaluation of the Problem and Virtual Solutions

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Interim Report: Compliance and Commercial Vehicle Operators – A Systems Evaluation of the Problem and Virtual Solutions

California PATH,
School of Policy, Planning and Development,
University of Southern California

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ABSTRACT

This report documents a review of the literature for commercial motor vehicle inspection and compliance stations and its relationship with the growth of truck travel over the next 25 years and the lack of concurrent capacity increases in staffing at such stations. Problems result in that more commercial vehicles will need to stop for inspection with longer queues at weigh stations associated with increased congestion, increased wait times, more idling trucks, and increased safety hazards. Alternatively, without stopping at inspection and compliance stations other problems will result such as roadway pavement and structure damage, and safety-related and security-related issues. Proposed advanced technological solutions to these problems are examined focusing on the four areas of pavement damage, safety, air quality, and security.

Key Words: truck travel, virtual weigh stations, commercial motor vehicle operations, weigh-in-motion stations

EXECUTIVE SUMMARY

This report documents a review of the literature for commercial motor vehicle inspection and compliance stations and its relationship with the growth of truck travel over the next 25 years and the lack of concurrent capacity increases in staffing at such stations. Problems result in that more commercial vehicles will need to stop for inspection with longer queues at weigh stations associated with increased congestion, increased wait times, more idling trucks, and increased safety hazards. Alternatively, without stopping at inspection and compliance stations will result in other problems such as roadway pavement and structure damage, and safety-related and security-related issues. Proposed advanced technological solutions to these problems are examined focusing on the four areas of pavement damage, safety, air quality, and security.

In the area of non-compliance and pavement damage, on average, approximately 2.7% of truck axles are overweight and contribute to about a 5.7% of documented pavement damage. Overall, in California such damage costs approximately between $20 and $30 millions annually for maintenance and rehabilitation. Of all the sites in California, 10 of them have the greatest pavement damage due to overweight axles, in particular, areas near the Ports of Long Beach and Los Angeles and the San Francisco International Airport. The elimination of overweight trucks at these sites could extend pavement life by an average of 10.7%.

In the area of safety-related issues, the Motor Carrier Safety Improvement Act of 1999 mandated the study of commercial vehicle crash causation resulting in the FMCSA and NHTSA launched the Large Truck Crash Causation Study (2001-2003). This and other studies have shown that commercial trucking vehicle miles traveled (VMT) have increased at a greater rate than passenger car VMT following 1980 deregulation of the trucking industry. While accidents have fallen per VMT, trucks are still more likely than passenger vehicles to become involved in accidents. Most crashes occur on weekdays, either in daytime between rush hours (0900-1400) or late night/early morning (0000-0700). Rural areas account for majority of fatalities and single-unit trucks crash primarily on less-than 50-mile trips. In terms of causal factors, two-lane undivided roads, roads away from traffic control devices, roads away from junctions account for majority of truck crash fatalities; urban freeway truck crashes disproportionately involve lane changes/merges; truck drivers safer than passenger car drivers except for tendency to speed; and training by trucking school, military, family, etc. is safer than training by trucking company.

In the role of non-compliance, trucking safety is largely a driver issue in that truck driver error is responsible in approximately 40% of truck-on-passenger-car crashes; approximately 25% of roadside truck inspections results in out-of-service, versus about 6% each for driver and hazmat inspections; drivers cited for size/weight violations are approximately 20% more likely to crash; noncompliance in driver-related issues (falsified or missing logbook, excessive hours of service, disqualified driver) results in about 50% greater likelihood of crashing; and brake failure is the most common vehicle issue for

about 30% of truck crashes during 2001-2003 study period involving the vehicle. Thus the usefulness of weighing and compliance stations is clear as it is important to find and remove non-compliant trucks off the road as quickly as possible. Increasing the inspectors' ability to identify trucks with defective brakes can save lives and money.

In terms of air quality, pollutants in diesel exhaust emissions contribute to air pollution with deleterious health effects (increased risk for heart attack, asthma, and premature death). Each year in the U.S., diesel emissions are responsible for 27,000 heart attacks and 2.4 million worker-days lost. California ranks 2nd in the nation for adult deaths associated with diesel particulate matter, and has the 5th highest death rate for children. Four of the top U.S. metropolitan areas with the greatest health impacts due to diesel are in CA (Los Angeles, San Francisco-Oakland-Fremont, San Diego-Carlsbad-San Marcos, and Riverside-San Bernardino-Ontario). Since the 1980's, there have been an increase in the number of lawsuits involving health effects due to diesel emissions. Usually plaintiffs claim that exhaust contributes to cancer or respiratory tract problems; occasionally they claim that exhaust "caused traumatic respiratory injury or brain damage." Numerous counties in California are classified as non-attainment areas. Gross emitting vehicles (trucks) – a vehicle emitting at least twice the allowed level of pollutant for a particular vehicle model – accounts for approximately 68% of all inspection and maintenance vehicle emissions; and about 90% are estimated to be located in 4 Air Quality Management Districts (South Coast Air Quality Management District, San Joaquin Valley Unified Air Pollution Control District, San Diego County, and metropolitan Sacramento). Increased emissions from high-emitting Mexico-domiciled trucks could occur if the moratorium is lifted and NAFTA provisions are implemented; truck idling is a significant contributor to emissions problem; and emissions around ports & illegal truck traffic in neighborhoods threatens health & safety.

In terms of security, prior to September 11, 2001, the focus of security for commercial motor vehicle operations was on vandalism, theft of the truck and its cargo, and interdicting the transport of illicit cargo and contraband. Immediately after September 11, 2001, the focus changed to include the use of stolen trucks and cargo with the intent of carrying out a terrorist act, especially using weapons of mass destruction. In 2003, the FMCSA surveyed 52 trucking companies about their perceptions of national security threats. The following list of threat perceptions from the survey responses are listed in decreasing order of priority:

- Stealing vehicles as instruments of terrorism
- Introduction of narcotics, WMD, contamination of food/water supply; miss-delivery of dangerous goods; truck entry to a consignor/consignee facility with intent to do harm
- Hijacking of trucks and drivers
- Theft of cargo and equipment, so-called "economic terrorism"
- Harm to employees, drivers' security traveling over roadways
- Theft of conventional arms, ammunition, and explosives
- Vandalism
- Disruption of services and roadways

- Not knowing the client and cargo shipped
- Organized crime and local gang elements
- Theft of nuclear weapons materials

Security measures implemented after 9/11 include procedural changes (improved preparedness, coordination with vendors); employment-related (enhanced background checks, ID badges, stricter discharge clauses); employee education and training; physical security devices (cameras, video surveillance equipment, guards, locks/seals); implementation of technology; communication procedures; information sharing initiatives; pre-screening systems, and legislation (Patriot Act, Border Security Act, Safe Explosives Act).

Technology implementation has been identified in the areas of vehicle monitoring and inspection, cargo detection and tracking, and access control. Vehicle monitoring includes closed-circuit television, and motion and fire sensors; vehicle inspection technologies include wireless systems based on DSRC; cargo detection includes non-intrusive inspection systems to detect WMD and the presence of humans; cargo tracking technologies include GPS, RFID, barcodes, satellites, web-based systems for loading of assets, and container sealing and tracking; access control includes the identification and authentication of individuals and vehicles for entry into restricted areas or to perform particular functions; and electronic access, electric fences, ID cards, password protection for engine start-up, seals, and tamper sensors.

In addition to investigating the problem frequency and its distribution, interviews with expert stakeholders were conducted to assess the capacity, performance, and costs associated with commercial motor vehicle inspection and compliance stations. Moreover, WIM technologies and their applications were also examined.

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1.0 INTRODUCTION

In the past five years, truck travel has increased 60 percent on California's highways. Yet, there has been no concurrent increase in the capacity of truck compliance inspection stations or officers assigned to truck enforcement. If a substantial number of trucks need to be inspected, then queues form at weigh stations, causing a number of problems. First, long wait time compromise already slim profit margins. Second, idling trucks waste fuel and contribute to air pollution. Finally, if queues back up into the highway, they can create safety hazards. Recognizing these problems, compliance inspection station operators allow trucks to bypass overcrowded stations. But for every ten percent by which a truck exceeds its weight limit, there is roughly a 40 percent increase in pavement and structure damage significantly increasing roadway reconstruction and resurfacing costs. And while truckers are among the safest category of drivers, crashes involving trucks are often catastrophic. More recently, concerns about terrorism have underscored the need for increased freight monitoring.

In response to these problems, the California Department of Transportation (Caltrans) has initiated research to test and evaluate Virtual Weigh Stations (VWS) for commercial vehicles. The first phase of a two year research project was initiated in January of 2006. This interim report presents the research team's understanding of the literature, available data, and expert opinions on the problem of commercial vehicle non-compliance with regulations related to pavement damage, safety, security, and air quality. In addition, this report addresses issues of capacity and performance related to California's weigh-in-motion technologies as well as a broader assessment of available WIM technologies and their real world applications.

2.0 PROBLEM FREQUENCY AND DISTRIBUTION

2.1 The Current and Future Distribution of Truck Travel in California

Truck traffic constitutes a significant portion of total traffic in California and of freight traffic nationwide. In 2004 and 2005, trucks accounted for 27 percent of total vehicle miles traveled (VMT) in California, and they are projected to account for almost 35 percent of total VMT in California by 2030 (CA DOT, 2005). There are approximately 15,200 miles of state highways in California and about 6.5 million trucks (CA DOT, 2001; 2005). In addition, California is a major point of entry for trucks entering from Mexico; in 2005, 24 percent of trucks entering the US from Mexico came through California (Office of Freight Management and Operations, 2007). (See also Appendix F)

2.2 Types of Trucks

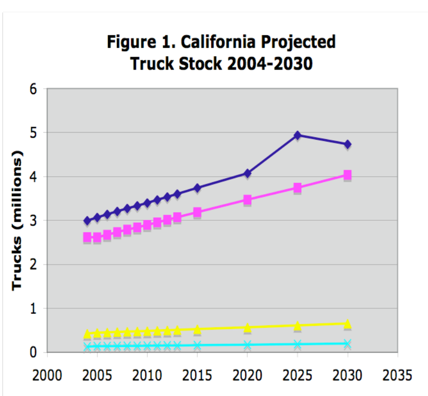
In 2001, the majority of trucks in California (84 percent) were single-trailer trucks, and multiple-trailer, single-unit, and single-unit with trailer trucks accounted for the remaining 16 percent (CA DOT, 2001). Most truck bodies are vans (60 percent), and flatbeds are also common (15 percent) (CA DOT, 2001). Almost all trucks have five axles (90 percent), as opposed to trucks with three, four, or more than six axles (CA DOT, 2001). While 21 percent of trucks on the road are empty, at any given time, 30 percent carry 33,000 to 60,000 pounds, and 44 percent carry more than 60,000 pounds (CA DOT, 2001).

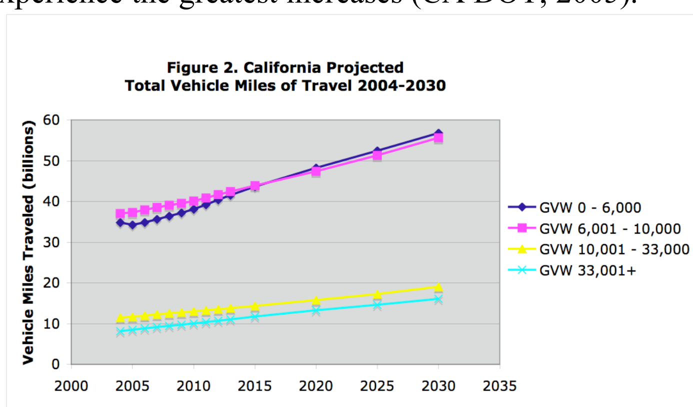
2.3 Destinations

Trucks have a variety of destinations. The most common is a distribution center; 24 percent of trucks on the road at any given time are traveling to distribution centers (CA DOT, 2001). Motels or rest areas and manufacturing sites are the next most common destinations, accounting for 13 percent and 12 percent of destinations, respectively (CA DOT, 2001). Over 60 percent of trucks make only 2-3 stops a day (CA DOT, 2001).

2.4 Projected Growth of Truck Stock and Truck Growth

Truck traffic is expected to grow in California in the next two decades, with the most growth occurring in urban areas and on the Interstate highway system (USDOT, 2002). Projections depend on assumptions of population growth, inflation, changes in personal income per person, fuel prices, and the prime lending rate (CA DOT, 2005). California will grow by 13 million people between 2000 and 2030 (NCHRP, 2007). The California Department of Transportation classifies trucks by Gross Vehicle Weight (GVW). Figure 1 and 2 depict projected increases in truck stock and truck vehicle miles traveled by GVW. For all GVW classes, truck stock is expected to increase; the lower weight classes will experience near doubling in stock, while the higher weight classes will only slightly increase their stock. Similarly, all GVW classes are projected to increase VMT by 2030, but the lower weight classes will experience the greatest increases (CA DOT, 2005).

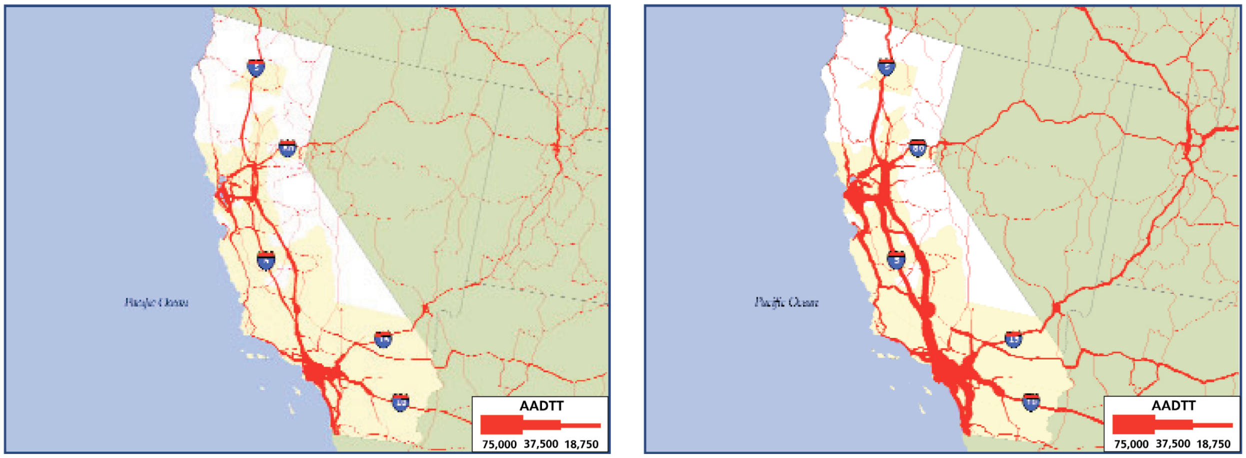




Source: CA DOT. California Motor Vehicle Stock, Travel, and Fuel Forecast (MVSTAFF) (1)

Figure 3 shows the expected increase in daily truck traffic from 1998 to 2020, according to the Federal Highway Administration (Office of Freight Management and Operations, 2006). The greatest increase in daily truck traffic will occur near urban hubs. As Table 1 shows, all modes of freight are projected to increase by 2020, and freight by highway will experience an increase from 1,108 tons in 1998 to 1,988 tons in 2020, with over a tripling in value (USDOT, 2002).

Figure 3. Estimated Average Annual Daily Truck Traffic, 1998-2020



Reproduced from: USDOT. Freight News (2002)

Table 1. Freight Shipments To, From, and Within California: 1998, 2010, and 2020

CALIFORNIA	Tons (millions)			Value (billions $)		
	1998	2010	2020	1998	2010	2020
State Total	1,360	1,980	2,435	1,218	2,564	4,315
By Mode						
Air	4	7	11	220	522	945
Highway	1,108	1,626	1,988	900	1,866	3,093
Other[a]	37	51	60	5	10	15
Rail	150	230	298	80	147	233
Water	62	65	78	13	19	29
By Destination/Market						
Domestic	1,231	1,750	2,105	956	1,940	3,130
International	130	230	329	262	624	1,184

Note: Modal numbers may not add to totals due to rounding.

[a] The "Other" category includes international shipments that moved via pipeline or by an unspecified mode.

Reproduced from: USDOT. Freight News (2002)

2.5 Pavement Damage

Santero et al. (2005) conduct the only available analysis of pavement damage due to non-compliance with commercial vehicle weight restrictions in California. They describe the problem of pavement damage resulting from overweight trucks in California as follows: "the percentage of pavement damage caused by overweight trucks is much greater than the expected damage measured by truck traffic volume on California highways" and this "costs the taxpayers millions of dollars every year in maintenance and rehabilitation costs" (p. 1). Caltrans has installed weigh-in-motion (WIM) sensors throughout California (see Figure 4) to collect data on traffic volume (including truck type, axle weight, and speed). Santero et al. (2005) use Caltrans WIM and cost data as well as standard pavement engineering damage equations and find the following:

- On average, 2.67 percent of axles are overweight and contribute to 5.74 percent of the pavement damage, across all sites.
- Extrapolating these figures to state highways, this damage costs the state of California approximately \$20 and \$30 million per year spent for maintenance and rehabilitation.
- Ten WIM sites are identified as having the greatest pavement damage due to overweight axles (see Table 2) and these sites include areas near the Port of Long Beach (9) and the San Francisco International Airport (7) (note that there is no WIM site around the Port of Oakland).
- The elimination of overweight trucks at these top ten sites could extended pavement life by an average of 10.71 percent.

For more information please see Appendix A.

Figure 4. California WIM Sites. (reproduced from Santero et al., 2005)

Table 2. Ten WIM Sites with Greatest Detected Pavement Damage. (reproduced from Santero et al., 2005, pg. 12)

Rank in Terms of Pavement Damage	Site Description	AADTT	Freight Through-put per Day (kN)	ESALs per day		Pavement Damage due to Overweight Axles*	Percent Increase in Pavement Life**	Percent of Axles Over Legal Limit
				Current	Redis-tributed			
1	Site No. 20, District 1, Humboldt County, Route 101, Postmile 65.6 NB, "Loleta"	1710	115598	849	715	19.44%	15.83%	12.60%
2	Site No. 86, District 1, Mendocino County, Route 101, Postmile 21.9 NB, "Ukiah"	2335	129464	739	645	15.71%	12.75%	6.48%
3	Site No. 86, District 1, Mendocino County, Route 101, Postmile 21.9 SB, "Ukiah"	2268	122768	777	678	15.66%	12.72%	7.00%
4	Site No. 20, District 1, Humboldt County, Route 101, Postmile 65.6 SB, "Loleta"	1773	103464	612	537	15.03%	12.22%	7.17%
5	Site No. 89090, District 11, San Diego County, Route 805, Postmile 24.5 SB, "Dekema"	12489	695805	3624	3221	13.62%	11.11%	5.18%
6	Site No. 15016, District 12, Orange County, Route 5, Postmile 25.8 SB, "Irvine"	14165	869913	4636	4168	12.31%	10.09%	4.75%
7	Site No. 33034, District 4, San Mateo County, Route 101, Postmile 17.5 SB, "Burlingame"	11664	540179	2018	1846	10.44%	8.56%	2.01%
8	Site No. 39, District 8, San Bernardino County, Route 30, Postmile 31.7 EB, "Redlands"	3155	183961	1122	1027	10.41%	8.51%	4.86%
9	Site No. 59060, District 7, Los Angeles County, Route 710, Postmile 11.5 SB, "LA - 710"	34732	2072297	9402	8674	9.55%	7.74%	3.99%
10	Site No. 91092, District 11, San Diego County, Route 805, Postmile 5.6 SB, "Poggi"	8574	485638	2288	2114	9.37%	7.58%	4.22%
Total		*92864*	*5319086*	*26068*	*23625*	*13.15%*	*10.71%*	*5.83%*

* based on percentage of total ESALs
** assuming all axles became legal and overweight portion of axles transferred to additional axles

Reference: Santero, Nokes, and Harvey. 2005. Virtual Weigh Stations: The Business Case. Technical Memorandum prepared for California PATH and Caltrans. TM-UCB-PRC-2005-3.

2.6 Safety

The passage of the Motor Carrier Safety Improvement Act of 1999 has led to considerable growth in scholarly understanding of the characteristics and causes of truck crashes in the United States. Here, we summarize key findings from the resulting literature. See Appendix B for a detailed discussion of the literature review results.

Commercial trucking has increased at a considerably greater rate than personal vehicle travel during the period following the 1980 deregulation of the trucking industry. Despite massive increases in the number of trucks on the road and in truck vehicle-miles traveled (VMT), however, trucking safety has shown considerable improvement, with declines across the board in fatal, injury, and property-damage-only accident rates. Overall, trucks are still more likely than passenger vehicles to become involved in accidents; moreover, safety improvements that have reduced fatalities from passenger vehicle-on-passenger vehicle accidents have led to an increase in the share of road deaths involving trucks. In particular, combination trucks are still far more likely than single-unit trucks and passenger vehicles to have fatal crashes.

Most truck crashes occur either in the daytime between commuter rush hours (9AM-2PM) or in the late night and early morning (midnight-7AM), and disproportionately on weekdays. Rural areas account for the majority of fatalities in truck crashes. Single-unit trucks primarily crash while on trips of 50 or fewer miles, while combination trucks are essentially equally likely to crash while on trips of any distance.

Rollovers are a leading cause of death in truck crashes (both single-unit and combination) in which no other vehicle is involved, with 64 percent of fatalities occurring during rollovers. In general, the heavier the truck or its cargo, the more likely it is to roll over. The opposite is true for jackknife: combination trucks that jackknife tend to pull much lighter trailers than those that do not jackknife.

Two-lane undivided roads account for the majority of fatalities from truck crashes. The vast majority of fatalities occur on portions of road away from traffic control devices (signals, stop signs, etc.) and junctions (driveways, intersections, ramps). On urban freeways, truck crashes disproportionately involve lane changes or merges. With the exception of speeding, drivers of trucks are less likely than those of passenger vehicles to make driving performance errors or to suffer from intoxication, fatigue, or illness. Payment issues are significant: simply put, as pay rises, crash risk falls. In particular, drivers paid by the hour and/or the mile tend to have fewer accidents than those paid as a percentage of the value of their load. Drivers trained by a trucking company are more likely to have an accident than those who attended a trucking school or received training from the military, a family member, or another source.

Trucking safety is largely a driver issue: among the 44 percent of truck-on-passenger-car crashes in which investigators found the truck at fault, driver error accounted for the primary factor 88 percent of the time, as opposed to only 10 percent for faulty equipment (roadway conditions being the remainder). This is not to say that equipment does not matter: nearly a quarter of roadside truck inspections conducted in 2004 resulted in an out-of-service order, quadruple the rates for driver and hazardous material inspections. Drivers cited for size/weight violations are more likely to have crashes than those not so cited, but noncompliance in directly driver-related issues (medical certification, logbook, hours of service, driver qualifications) is an even better indicator of crash likelihood. Among vehicle issues, by far the most common problem is brake failure.

2.7 Air Quality

The state of California is home to the world's third busiest ports, the ports of Long Beach and Los Angeles in San Pedro Bay, as well as the second largest border crossing with Mexico in the U.S. As a result, California's roadways carry more commercial vehicle truck traffic than any other state in the U.S., and nationally, this traffic is expected to grow by 50 percent by 2020 (FHWA, 2006). Commercial vehicle trucks use diesel engines because they are 25 to 35 percent more fuel-efficient and have greater durability than gas engines, but diesel exhaust releases 100 times more particles of soot than a gas engine under the same conditions (U.S. Government Accountability Office, 2004; American Lung Association, 2000). Diesel engines are responsible for approximately 66 percent of particulate matter almost 26 of nitrous oxides in the air from on-road sources (American Lung Association, 2000). Diesel exhaust has serious effects on human health; it is classified by California as a carcinogen and contains forty hazardous air pollutants listed by the Environmental Protection Agency (EPA). Not surprisingly, California is home to four of the top 25 metropolitan areas in the U.S. with the greatest health impacts due to diesel: Los Angeles, San Francisco-Oakland-Fremont, San Diego-Carlsbad-San Marcos, and Riverside-San Bernardino-Ontario, ranking two, seven, 21, and 25 respectively (Clean Air Task Force, 2006).

Because of their serious health effects, the gaseous emissions from diesel engines have been the subject of increasingly strict regulation for more than 30 years, yet these emissions remain a problem. The large scope and high cost of the enforcement required to ensure compliance with current diesel emissions regulations on engine manufacturers and commercial vehicle operators raises questions about effectiveness. The history of compliance with regulations on diesel emissions is rife with examples of deliberate attempts by engine manufacturers and commercial vehicle operations to skirt these regulations.

In Appendix D the literature is reviewed to examine the magnitude of diesel emission health effects as well as the challenges and efficacy of the enforcement of regulations of diesel emissions. It begins with a discussion of the body of evidence on the health effects of diesel emissions. Next, background is provided on the agencies responsible for regulating and enforcing compliance with diesel emissions regulations in California and the nation. This is followed by a description of the regulations on diesel emissions and enforcement procedures as well as an analysis of the barriers to effective of enforcement. Next, the voluntary and incentive based programs sponsored by California and federal agencies to promote compliance are described. It concludes with a discussion of future regulatory and enforcement challenges to diesel emissions posed by the North American

Free Trade Agreement (NAFTA) and an assessment of future prospects for enforcement and compliance in California. What follows is a discussion of some key compliance related issues.

Residential Truck Emissions and Health

In a study of traffic in Hunts Point, New York City, Lena et al. (2002) measured emissions of elemental carbon and $PM_{2.5}$ on sidewalks and assessed spatial variations in concentrations with respect to traffic density by vehicle type. Hunts Point is located on a peninsula in the South Bronx and is home to 10,000 residents, 3,000 of whom are children. The two main ethnic groups in the area are Latinos (73 percent) and African Americans (25 percent). A key feature of the region is that it is a hub for freight transportation between New York, New Jersey, and Connecticut. The study was initiated in response to residents' concerns about exposure to traffic emissions. After comparing emissions from cars, light trucks, and large diesel trucks, Lena et al. (2002) found the highest correlation with emissions of elemental carbon and $PM_{2.5}$ from large diesel trucks ($r = 0.92$, $r = 0.72$).

A study in the Netherlands by Brunekreef et al. (1997) examined lung function among children living in six areas near major motorways. Air pollution from truck traffic was assessed by measuring the distance from children's homes to motorways, and traffic density on motorways was ascertained by counting passing trucks. In addition, PM_{10} and NO_2 concentrations were measured inside schools of children in the study. Researchers found a clear exposure-response relationship between distance from home to motorway and child's lung function. Children who lived within 100 meters of motorways or near the highest truck traffic densities had decreased lung function compared to children living in other areas.

A later study in the Netherlands by Janssen et al. also measured respiratory health of children attending schools within 400 meters of a motorway (Jannsen et al., 2003). Distance between schools, homes, and motorways was measured, and traffic counts were used to assess exposure levels. Health effects assessed in the study included bronchial hyper-responsiveness and allergic sensitization of airways. Researchers found that truck traffic and its associated air pollutants were associated with chronic respiratory symptoms among children who lived close to motorways.

Vulnerable Populations and Communities

In general, health effects from diesel exhaust emissions are most serious among children, the elderly, and people with preexisting heart and lung conditions. Most children are also more active than adults, have a higher respiratory rate, and spend more time outdoors, so the effects of diesel emissions are particularly egregious (Gauderman et al., 2000). One of the most comprehensive studies on the health effects of air pollution on children is the Children's Health Study. Started in 1993, the study followed 6,000 children living in Southern California. The study found that children living in communities with higher levels of NO_2 and PM experience 10 percent slower lung function growth (Künzli et al., 2003). Children with asthma living in such communities suffered from more bronchitis as well as persistent phlegm production (Künzli et al., 2003).

In addition, residents of communities near sources of concentrated diesel emissions, such as ports and major truck routes, have also been shown to be at significant risk. Most of these communities are composed of minority and economically disadvantages populations. In California, the serious health effects have been documented on several communities with close proximity to truck traffic, West Oakland, Bayview Hunters Point in San Francisco, and Mira Loma (near Riverside).

California's Manufacturer-Related Enforcement Procedures

In California, engine manufacturers are required to self-certify engines before sale. Such self-certification ensures that engines have been built to meet California state laws to minimize emissions. In addition, the CARB cooperates with the California Highway Patrol to test heavy-duty trucks for excessive emissions. Inspection and testing procedures apply to any heavy-duty truck traveling through the state, including those registered in other states or other countries. The two main programs CARB runs are the California Heavy-Duty Vehicle Inspection Program (HDVIP) and the Periodic Smoke Inspection Program (PSIP). In HDVIP, field inspectors test emissions of vehicles with a gross vehicular weight over 6,000 pounds at California Highway Patrol weigh stations, fleet facilities, ports, roadside locations selected randomly (California Air Resources Board, a). Under Chapter 727 Statutes of 1998, CARB must also conduct the HDVIP and random roadside inspections at California-Mexico border crossings.

Under California's Periodic Smoke Inspection Program (PSIP), owners of all fleets of at least two heavy-duty vehicles based in California must annually perform a snap-acceleration test and inspect for tampering (California Air Resources Board, b). Engines in the first four model years are exempt; for instance, in 2000, all engines model years 1997 to 2000 would be exempt (California Air Resources Board, 2006a). Although it lacks the resources to test all engines itself, the CARB randomly checks a representative sample of vehicles' fleet maintenance and inspection records (California Air Resources Board, 2006a).

Between June 1998 and December 2004, under HDVIP, the CARB performed 116,734 visual inspections and issued 7,724 citations. Of all vehicles tested, 7.0 percent failed, and $1,848,000 penalties were assessed, with $1,457,037 actually collected (Jacobs, 2005a). Penalty funds are used to research clean diesel technology, support the Carl Moyer Program, which funds public or private entities that use clean engines, and support the Smog Check Program (Jacobs, 2005a). In 2006, CARB's HDVIP program conducted 17,585 inspections and found 703 violations, which yielded $205,200 in assessed penalties, of which $199,807 has been collected. According to an expert at CARB, about 70 percent of companies comply with self-certification regulations at some level. The 30 percent that ignore regulations are often large companies that have been in existence for long periods of time and discontinued annual self-certification after years passed in which they were never audited.

Ultra-Low Sulfur Diesel (ULSD) Fuel Requirement

EPA initiated implementation of a new ULSD fuel requirement in 2006. In the 2005 Highway Diesel Fuel Pre-Compliance Reports, the EPA stated that refiners were prepared to comply with the new sulfur standard by the June 2006 deadline and would be ready to provide ULSD fuel nationwide. The EPA estimated that 90 percent of all diesel fuel produced in 2005 would be low in sulfur (U.S. Environmental Protection Agency, 2006i). However, EPA is continuing to experience difficulties implementing its new ultra-low sulfur diesel requirements due to industry stakeholder concerns. The rule was promulgated in 2001, which provided industry with six to ten years to develop engines and fuels that meet the new standards (U.S. Government Accountability Office, 2006). However, trucking companies worry that the new technology required under the 2007 rule will be too costly and will decrease fuel efficiency to a greater extent than EPA has predicted (U.S. Government Accountability Office, 2006). The GAO found that nine out of ten trucking companies they contacted admitted that they would stock up on older trucks again before the new rule is implemented, which could again disrupt markets and delay emissions reductions (U.S. Government Accountability Office, 2006).

Diesel Defeat Devices

In 1998, the EPA lowered standards for NO_x emissions in 2004 to 2.5 grams, which gave engine manufacturers time to gradually producer cleaner engines (U.S. Government Accountability Office, 2004). However, between 1987 and 1998, EPA found that rather than produce cleaner engines, manufacturers had sold 1.3 million engines that contained illegal software to mask emissions by altering the timing of fuel injection. Known as "defeat devices," the software increases fuel efficiency but also increases NO_x emissions two to three-fold; however, the software hides these excess emissions during testing procedures (U.S. Government Accountability Office, 2004; U.S. Department of Justice, 1998). The sale of these engines contributed to an excess of 15,748,000 tons of NO_x emissions (U.S. Government Accountability Office, 2004) and over the life of the vehicles with the devices "would cause 2,500 premature deaths, 5,000 hospitalizations, and cost $6 to $21 billion dollars in public health expenses" (American Lung Association, 2004).

In California, it is estimated at in 2007 there were approximately 396,050 medium-heavy and heavy-duty diesel trucks in operation. Of these, 70,075 need to be reflashed, meaning that they need to have the correct low NO_x software installed. However, 28 percent have yet to be reflashed. By 2020, CARB expects that about 2,000, or10 percent, will still need to be reflashed.

Truck Idling

Throughout the duration of their trucking, most truck drivers idle their engines during rest periods in order to control the temperature of the cab, run electrical appliances, to keep the engine heated, or while awaiting shipment drop off or pick up (U.S. Federal Highway Administration, 2005). Ports are one example of an area with frequent truck idling and high levels of emissions because of the heavy volume of trucks passing through each day. Particularly because shipments are not always timed perfectly with the arrival of trucks, ports are a hot spot for truck idling. According to a report by the Federal Highway Administration, most trucks idle for approximately six hours each night and between 1,800 and 2,400 hours per year (U.S. Federal Highway Administration, 2005; Turchetta, 2005). Each hour a long-haul truck idles, it burns about 3.8 liters of fuel, and overall, idling trucks waste up to 3.78 billion liters of fuel each year (Turchetta, 2005). This wasted fuel yields 163,000 metric tons of NO_x, 4,535 metric tons of PM, and 9.98 million metric tons of CO_2 every year (Turchetta, 2005).

In a national survey of line-haul truck drivers, Lutsey et al. found that engines idled for 34 percent of total run time on average and that each truck idled approximately 1,700 hours each year (Lutsey et al., 2004). Climate control was found to be the main reason for truck idling, followed by powering accessories, "avoiding start-up problems, drowning out other noise, and reducing engine maintenance" (Lutsey et al., 2004, p. 1880). Lutsey et al. determined that the average truck idles about $2,000 for each year's worth of fuel during idling; however, an estimated 25 percent of drivers used over $3,000 worth, and 10 percent used over $4,500 worth (Lutsey et al., 2004).

To address excessive idling of trucks, California has passed regulations (Section 2485 – Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling) effective February 1st, 2005, which prohibit drivers of any diesel-fueled commercial vehicles with a gross vehicular weight ratings over 10,000 pounds operating in California from idling the vehicle's primary diesel engine for more than five minutes, with some exceptions[1]. In addition, truck drivers may not idle a diesel-fueled auxiliary power system for over five minutes to "power a heater, air conditioner, or ancillary equipment on the vehicle during sleeping or resting in a sleeper berth for greater than 5.0 minutes at any location within 100 feet of a restricted area" (California Air Resources Board, 2006b; California Air Resources Board, 2005a). The EPA has no such idling regulations at the federal level. In 2006, CARB conducted 1990 idling inspections and issued 90 citations/notifications of violation. There is currently a bill pending (AB 233-Jones) that would increase funding for enforcement of idling regulations as well as CARB's other enforcement programs (Personal communication, Jacobs).

The North American Free Trade Agreement

In addition to truck travel within the U.S., truck traffic between the U.S. and Mexico pose significant challenge to reducing emissions. Since the initiation of the North American Free Trade Agreement in 1994, trade between Mexico and the U.S. has increased significantly. Trucks are one of the key freight carriers delivering goods across the U.S.-Mexico border. California is home to the second largest border crossing at Tijuana-Otay Mesa (near San Diego) (Jacobs, 2005b). Each day, about 3,500 trucks enter California from Mexico (Jacobs, 2005b). The U.S. has held a moratorium on issuing permits to companies seeking to operate heavy-duty diesel trucks in the U.S. since 1982 (Putnam,

[1] CARB allows trucks to idle due to traffic conditions, when queuing while at least 100 feet from homes and schools, in order to check for safe operating conditions, or for mandatory tests, repairs, or diagnostics.

2003). The moratorium limits non-licensed Mexican trucks traveling in the U.S. to a 20-mile commercial zone near the border (Jacobs, 2005b).

In 2006, 17,585 heavy-duty commercial vehicles were inspected by CARB at ports of entry, border crossings and other roadside locations throughout California. Over four percent (703) failed to meet California's emissions specifications and were issued violation notices. An additional 1,230 were issued notices of violation for engine software violations. In the California Mexican border region, 2,070 heavy duty commercial vehicles were inspected and 300 were issued violation notices for a failure of over 14 percent. The CARB issued over $500,000 in penalties for these emissions violations collected over $493,000 in penalties (including penalties collected from violations issued in past years). CARB tracks vehicles numerous ways including by vehicle identification number to avoid owner-operated truckers who receive tickets from closing down their business and reopening under a new name.

Most experts predict that an end to the moratorium would likely lead to an influx of Mexican trucks on U.S. highways because of the significantly lower service costs of Mexican trucks. The CARB projects that there will be approximately 30,000 extra truck crossings each day into the U.S., if NAFTA provisions are implemented (U.S. Department of Justice, 1998). The age of the Mexico fleet is of concern: 66 percent of Mexican trucks are models that are not fully electronically converted, which means that they lack the electronic fuel injection and computer controls necessary to reduce emissions (Jacobs, 2005b). In addition, a quarter of Mexican trucks are pre-1980 models, which are known to emit high levels of NO_x and PM (Jacobs, 2005a). Mexico did not set standards for its heavy-duty diesel vehicles until 1994, when its standards were aligned with those of the U.S. EPA. However, it did not update its standards to match U.S. EPA’s tighter restrictions on NO_x and PM emissions for post-2003 models (California Air Resources Board, 2006a). Thus, even though Mexico’s diesel engine emissions standards are the same as the U.S. standards for 1994 to 2003 models, the majority of its trucks do not meet U.S. standards and will continue to emit significantly higher levels of air pollutants than are allowed in the U.S. (Jacobs, 2005b). In addition, access to cheaper Mexico-domiciled trucks could reduce freight costs and increase demand for trucking services and in turn increase emissions (Putnam, 2003).

CARB estimates that once the border opens to Mexican commercial trucks, the two border crossings will experience an increase from 3,500 crossings per day to between 12,250 and 17,500 per day (California Air Resources Board, 2006a). The increased traffic could create an additional 50 tons of smog-forming pollutants each day (California Air Resources Board, 2006a). Since 1999, California has conducted its HDVIP program at the two border crossings and in the border area; since then, the opacity test failure rate has been consistently higher at the border region than in the rest of the state, which is likely due to the older age of Mexico’s truck fleets (California Air Resources Board, 2006a). Based on anecdotal reports, CARB expects that the majority of new truck trips will be to and from the Ports of Long Beach and Los Angeles.

According to CARB, other possible strategies include expanding the Tijuana Inspection and Maintenance Program into urban areas of Baja California and to cover all vehicles, continuing enforcement of the Heavy Duty Vehicle Inspection Program in the border region, and continuing "aggressive collections of delinquent HDVIP citations at the Mexican border and statewide" (Jacobs, 2005b, p. 4).

While Mexico has not altered its emissions regulations, in 2005 it announced a demonstration project that would retrofit diesel trucks based in Tijuana, Mexico with oxidation catalysts and particulate filters used in combination with ultra-low-sulfur diesel fuel (U.S. Department of State, 2005). The project is part of the Security and Prosperity Partnership of North America, which aims to "address the threat of terrorism and enhance North American security, competitiveness and quality of life" (U.S. Department of State, 2005). In addition, Mexico has announced that it plans to require the use of ultra-low sulfur diesel in border regions as of 2007, and it hopes to extend the regulation to the whole country by 2009.

2.8 Security

Prior to September 11, 2001 (or 911), 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 911, 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. See Appendix C for a detailed discussion of the literature review results.

A number of measures were implemented in direct response to the attacks of 911 that included use of cameras, locks and seals, and global positioning satellite systems (GPS). Additional technology system changes, either planned for or implemented since the immediate aftermath of the 2001 terrorist attacks, may be classified into the following groupings (Friedman and Mitchell, 2003; Anderson et al, 2005; Brown, 1995, Wilkins, 2002; Slaughter et al., 2003):

- Vehicle Monitoring
    - Closed circuit television (CCTV), digital recording, remote viewing, covert CCTV, and detection devices such as for motion, fire, and burglary sensors.
- Vehicle Inspection
    - Wireless inspection systems based on dedicated short-range communications (DSRC) at 5.9 GHz.
- Cargo Detection
    - Non-intrusive inspection technologies, e.g., x-ray, gamma ray, that can detect WMD including radiological, chemical, and biological type weapons that are inside a container (us treasury advisory committee on commercial operations of the US CUSTOMS SERVICES

    - Non-intrusive technology to electronically detect the presence of persons inside of shipping containers (human occupancy detection)
    - Non-intrusive technology to scan and detect cargo containers for special nuclear material by means of neutron or gamma rays
- Cargo Tracking
    - Includes technologies such as GPS, RFID, barcodes, satellites, and web-based systems that can be used to identify cargo loaded into a container and/or to track the container. Such technologies enables the identification of assets being loaded into a container, the sealing of the container, the tracking of the container, and enables the owner of customers to determine in real-time the location and integrity of the container at, for example, the port of entry, and, if necessary, to alert security or to immobilize the vehicle.
- Access Control
    - Includes technologies to identify and authenticate individuals or vehicles allowed into a restricted area or to authenticate a person to drive a particular vehicle or perform a restricted function such as loading cargo into a container. Include items such as electronic access, gates, electric fences, identification cards (picture badges, biometrics, smart cards), coded lock and entry, truck and trailer locks, seals and tamper sensors, remote engine shut-off, and identification or password protection for engine start-up.
- Communications
    - Include two-way radios, panic buttons, and cell phones.

Pre-screening and pre-processing systems are designed to improve goods movement security and maintain goods movement efficiency by screening cargo and processing customs paperwork from authorized shippers and carriers before a shipment arrives at an international gateway (seaport, airport, border crossing). Examples of these systems include the following:

- *Container Security Initiative (CSI)*: A program to tighten and expand cargo-reporting requirements by pre-screening containers before reaching US ports
- *Border Release Advanced Screening and Selectivity (BRASS)*: A cargo processing system using barcode technology to expedite release of high-volume shipments at borders
- *Customs Automated Forms Entry System (CAFES)*: A system using barcode technology to reduce paperwork and waiting time at the border
- *Customs Trade Partnerships Against Terrorism (C-TPAT)*: A joint government and business initiative to protect cargo security entering the US while improving flow the trade. This program allows low-risk carriers to receive streamlined border clearance approval
- *Free and Secure Trade (FAST)*: A bilateral clearance process between Canada and the US for known low-risk shipments handled by C-TPAT-approved motor carriers.

Potential fallout from implementing security-related measures for the trucking industry, especially at ports of entry and international borders, are delays associated with intensified inspections, and such delays could undermine the competitiveness of exports by increasing company transaction costs.

In 2003, an investigation into security measures in the commercial trucking industry, sponsored by the Federal Motor Carrier Safety Administration (FMCSA), was conducted by means of a survey of 52 trucking companies. Twenty responses were received for a 38.5% response rate and respondents reported the following functionality associated with their trucking businesses: general freight, HAZMAT, food and alcohol, military freight, and dry bulk tank carriers. The trucking companies were not randomly selected but were biased toward large companies. In terms of threats to security, the survey asked the question: *What do you perceive to be the key national security (terrorism-related security) threats to your commercial trucking operations?* Survey responses are shown in Table 3 (Friedman and Mitchell, 2003).

Table 3 Perceived Threats to Trucking Operations

Perceived Threats to Trucking Operations	Percentage of Total
Stealing vehicles to be used as instruments of terrorism	35%
Introduction of narcotics, WMD, contamination of food/water supply; miss-delivery of dangerous goods aimed at a disastrous result; truck entry to a consignor/consignee facility with intent to do harm	30%
Hijacking of trucks and drivers	25%
Theft of cargo and equipment, so-called "economic terrorism"	25%
Harm to employees, drivers' security traveling over roadways	25%
Theft of conventional arms, ammunition, and explosives	20%
Vandalism	20%
Disruption of services and roadways	10%
Not knowing the client and cargo shipped	10%
Organized crime and local gang elements	10%
Theft of nuclear weapons materials	5%
None	10%

Source: Transportation Research Board, "Security Measures in the Commercial Trucking and Bus Industries Synthesis 2", Federal Motor Carrier Safety Administration, 2003.

Note that the total percentages exceed 100 percent because respondents were allowed to select all perceived threats that applied to their specific circumstances and setting.

The FBI estimates that in the range of $12 billion to $20 billion is lost annually in truck cargo thefts, which is less than one-half of a one percent of the Bureau of Census estimate of approximately $4.9 trillion in annual U.S. truck cargo. The American

Trucking Association believes that even the higher FBI estimate is a substantial underestimate by a factor of possibly 10 to 20 (Friedman and Mitchell, 2003).

In general the security literature is lacking in documenting more quantitative assessments of the 1) extent of the terrorist threat to the trucking industry and 2) effectiveness of implemented security-related measures. For example, while there are surveys indicating the trucking industry's perceived threats (see Table above) there is no central database for the collection of such data, whether it be vehicle thefts, cargo thefts, security breaches by drivers or outsiders.

Finally, the Senate is expected to vote any day now on its version of a measure already passed by the House in May that, in brief, would impose deadlines on background checks for port workers, expand a program to screen for "dirty bombs" and authorize $400 million to help ports bolster anti-terrorism defenses at ports, including the Los Angeles-Long Beach port complex (Simon, 2006).

3.0 EXPERT INTERVIEWS

Researchers with Innovative Mobility Research (IMR) at California Partners for Advanced Transit and Highways (PATH) conducted 20 stakeholder interviews with representatives from public and private organizations, including federal, state, and local commercial vehicle regulatory and enforcement agencies, trucking companies, and technology vendors. The general findings from these interviews are summarized here.

3.1 Problems and Locations

Experts were asked to identify the greatest weaknesses/problems of the current commercial vehicle screening/enforcement processes in CA and/or U.S. and where these problems tend to be located. Experts were interviewed from Caltrans, California Highway Patrol (CHP), California Air Resources Board, the Ports of Oakland, LA/Long Beach, and Sacramento, a short-hall trucking company operating out of the port of LA/Long Beach, FMCSA, U.S. Coast Guard, PrePass, and several technology vendors. They identified the following problems:

- The number of trucks continues to increase; however, the number of inspections officers does not increase to meet the demand for more inspections.
- Lines form at CVEF and idling trucks back up onto roadways causing roadway hazards and air quality concerns.
- Overweight trucks wait for lines to form at CVEF and the facilities to close so they can bypass without an inspection.
- Truck drivers avoid inspection facilities by exiting the freeways, using non-truck routes, and driving on residential streets.
- Many trucks do not carry hazardous materials placards thus making dangerous materials/chemicals difficult to track.

- Although California has strict fuel and emissions standards, a lack of CARB resources makes these standards difficult to enforce; it is difficult to enforce emissions regulations because the work load is extremely high and budget restrictions place limitations on staff.
- Truck owners register their vehicles out of state to avoid having to buy CARB diesel.
- Short-hall truckers often use routes which do not require their trucks to pass inspection stations and thus they often operate with unsafe breaks, bad tires, and no insurance.
- Owner-operated trucking companies often shut down and reopen under new names to avoid paying fines.

The experts also identified a number of locations throughout the state where these problems frequently occur. See Table 4.

Table 4. Locations of Commercial Vehicle Non-Compliance Related Problems.

Location	Problem
State Route 47	The Shoolerheim Bridge on State Route 47 carries an estimated 1,000 trucks per day. Sample data from this area suggests that many of these trucks are 100,000lbs, which is overweight for the bridge.
710 Freeway	Many overweight trucks never enter the 710 and instead drive on an access road adjacent to the 710 Freeway. This site is a problem because of its geography. The freeway runs from the Port of Long Beach into downtown Los Angeles with the Los Angeles River on one side.
405 Freeway	A truck hit the scale house and destroyed the weigh station. Due to a lack of funding this site has not been rebuilt.
110 Freeway	Trucks will use non-truck routes to avoid the CHP. The 110 Freeway once had an inspection station that is no longer in use and trucks often use non-truck routes and neighborhoods to avoid the 405 inspection station.
I-5, 101 and 126 Freeway	These problem locations are outside of LA. Trucks coming down I-5 bypass the 101 inspection station by taking the 126. Trucks traveling on the 126 drive directly through the city of Moore Park and cause concern among residents of the city.
Highways 37 and 40 and 118 Freeway	These sites are located in San Bernardino County. Trucks traveling on these routes are usually coming from rock queries and are often overweight. These trucks damage the roadways and are difficult to track because of the sheer volume of trucks traveling on these roadways.
The Ports (LA/Long Beach/Oakland/ Sacramento	The expert described the ports as "the worst offenders." The Port of Oakland does not have a CVEF or WIM nearby and trucks leaving the Port often cut through the city of Oakland, creating emissions and air quality concerns.
Interstates 80 and 5 and 880, 580 and 205 Freeways:	These sites have high volumes of unscreened trucks traveling from the Ports of Oakland and Stockton to destinations throughout the Central Valley and into San Jose and San Francisco.

Experts were also asked how they thought these weaknesses/problems should be addressed:

- Representatives from Caltrans and the Ports want to first set up a system to collect data on overweight trucks, including using mobile VWS systems to collect data in a variety of locations (e.g., freeways, bridges, near ports, on rural highways and to track trucks using non-truck routes).

- Some representatives from Caltrans and PrePass want the PrePass program to become mandatory for all trucks operating in California,
- Representatives from Caltrans and various technology vendors believe more CVEF should be built, more officers should be assigned to commercial vehicle enforcement, more mobile WIM units should be deployed on rural roads and around ports, and port operators should be held accountable for overweight trucks leaving their facilities.
- Other experts from Caltrans, CHP, FMSCA, U.S. Coast Guard, and various technology vendors would like to use both mobile and fixed VWS technologies to identify overweight trucks, track goods movements, and conduct electronic screening and credentialing.

3.2 Capacity and Performance

Experts were asked about their general understanding of the capacity, performance, and costs of the current screening processes in California (e.g., at CVEF and targeted enforcement):

- According to the U.S. Coast Guard, their capacity to thoroughly inspect trucks is inhibited by limitations in enforcement policies. The Coast Guard has limited jurisdiction on cargo container inspections and can only enter containers with hazardous materials placards.
- In cases where trucks are lacking a hazardous materials placard, Customs agents must be called to conduct the inspection. This slows down the inspection process.
- Representatives from CHP and Caltrans stated that the average commercial vehicle inspection officer can only screen/inspect about eight trucks per shift.
- CHP's capacity to conduct thorough inspections is restricted by the sheer number of inspections that must be done. Level Three inspections (paperwork only) are the most common types of inspections.
- During a typical two day CARB strike force, 30 to 40 citations are issued for emissions violations, including excessive smoke and non-compliant engine software upgrades.
- According to representatives from Caltrans, the high cost of building/maintaining CVEF and WIM sites prohibits the construction of new sites.
- According to CHP and Caltrans, WIM sites often experience technical difficulties and their performance, reliability, and accuracy is altered by weather conditions (i.e., extreme heat or cold) and by traffic volume (i.e., equipment in areas with high traffic volume often breaks, needs repair and/or replacement).
- According to Caltrans, WIM sites are only calibrated by IRD about once per year. Due to a lack of regular calibration, some Caltrans representatives

believe that these sites are inaccurate and can never be used for enforcement purposes.

Next, experts were asked about their agencies/organization's interest in VWS applications:

- Representatives from the ports are interested in applying to streamline import/export of cargo moving though the ports (i.e., create a main gate to process trucks arriving at the port, identify driver and truck, and assign the truck to the appropriate terminal).
- CHP is interested in applying technologies to assist officers in identifying which trucks should be stopped for a roadside inspection and as an enforcement tool in areas where traditional enforcement may be difficult (i.e., busy roadways, bridges, rural areas).
- Caltrans would like to investigate technologies application to reduce pavement and structural damage and costs associated with building traditional static scales.
- According to Caltrans representatives, Caltrans wants to create a screening system that is better, faster, and cheaper than the current system.
- Federal agencies are interested in the potential to use VWS at boarder crossings, ports of entry, to track goods movements and hazardous materials, monitor stolen trucks, and to reduce human trafficking.
- Vendors would like to contract with researchers and Caltrans to design "better WIM/VWS screening systems".

3.3 Application of Virtual Weigh-in-Motion

Experts were asked to explain their organization's views on the use of VWS technologies to identify overweight vehicles, improve roadway safety (i.e., DSRC devices to ensure that trucks maintain good safety records and proper credentials), identify emissions violations (i.e., emissions sensors used to ID gross polluters), and improve homeland security (i.e., use cameras, license plate readers, and gamma ray detectors to screen for illicit cargo, human trafficking, and potential weapons). The following summarizes their responses:

- Caltrans, CHP, PrePass, the ports, and FMCSA believe that VWS technologies have the potential to be used to identify overweight trucks, for electronic credentialing, and for homeland security purposes (i.e., use cameras, license plate readers, and gamma ray detectors to screen for illicit cargo, human trafficking, and potential weapons) on various types of roadways (i.e., near ports, in rural areas and on freeways).
- The U.S. Coast Guard is interested in the application of gamma ray detectors and other heat seeking devices at and near ports of entry to screen for potential weapons and human trafficking, and to track goods movements (i.e., DSRC and RFID tags).

- Trucking companies are interested in using electronic credentialing and VWS in areas frequented by owner-operated truckers (i.e., near ports, industrial areas, and alternative routes used to avoid weigh stations) to catch non-compliant truckers (e.g., without proper insurance, registration, etc.).
- The Ports would like to investigate how remote emissions sensing technologies can be used to identify gross polluters near the ports and to electrically identify trucks and drivers arriving at the ports.
- CARB, PrePass, IRD and many Caltrans representatives feel remote emissions sensing technology is inaccurate and not reliable; however, other technology vendors believe that remote emissions sensing technologies can be used to identify gross polluters at freeway speeds.

When asked to share what they know about the PreePass program, experts had varied responses:

- Some representatives from Caltrans would like to see the PrePass program become mandatory for all trucks; they support the program because it saves time and money for both commercial vehicle operators and on commercial vehicle inspections.
- Other Caltrans representatives and technology vendors believe that the PrePass program is underutilized and is often abused by devious truckers who switch and share transponders.
- Representatives from the PrePass program report that their program currently serves over 65,000 motor carries, 376,000 trucks are enrolled nationwide, and 316,000 trucks are enrolled in California.

Experts were then asked to explain (their/their organization's) views on the use of mobile and fixed VWS sites:

- Many representatives from Caltrans, the Ports, and trucking companies support the use of both mobile and fixed VWS technologies to identify overweight vehicles (e.g., use license plate readers), improve roadway safety (e.g., DSRC devices to check truck credentials), identify emissions violators (e.g., use emissions sensors to identify gross polluters) and to improve homeland security (e.g., use gamma ray detectors to monitor human trafficking, illicit cargo and potential weapons). These experts support the use of these technologies in all locations (e.g., truck-only routes, alternative routes used to avoid inspection stations, rural roads, urban high-volume roads, near ports, on bridges and at border crossings).
- Other Caltrans representatives caution that VWS systems only work accurately on certain types of roadways (i.e., where roadways are level and smooth).
- Several technology vendors and Caltrans representatives support the use of both mobile and fixed VWS sites. These experts believe that it is more cost effective to deploy mobile units on all types of roadways.

- According to one vendor, static weight scales are the most accurate with an error of ± 10 percent. However, both fixed and portable sites can be designed to be accurate and reliable.
- Other vendors advocate using fixed weight sensors to identify overweight trucks, imaging technology to identify license plates and DOT numbers, and DSRC devices to ensure that trucks maintain good safety records and proper credentials.
- Representatives from the CHP believe that it is important for officers to make traditional roadside stops to check for driver fatigue, DUI's, and drivers who are on stimulant drugs; however, they support the use of mobile VWS units (i.e., near ports, in rural areas, in high traffic locations and on routes used to avoid inspection stations) to assist with screening for credentialing, registration, and weight.
- FMCSA supports the use of both mobile and fixed weigh scales and believes that a combination of these technologies can be used to track, inspect and regulate more trucks. FMCSA recognizes the costs associated with building CVEFs and believes that states are not willing to pay for these sites. He feels that mobile VWS units (which do not cost as much as fixed sites) are great alternatives.
- CARB believes that VWS technologies may work for weight enforcement but the remote emissions sensing technology is not accurate.

Experts were given two scenarios, a semi-automated system and a fully automated system, and were asked to provide feedback. The first involved a semi-automated system accompanied by an officer. More specifically, a fixed or mobile site that can be equipped with weight sensors, when a truck drives over these sensors the weight data is immediately sent to the computer monitoring system, which in turn notifies the officer of a potential violation. The officer can then be dispatched to intercept the vehicle and can either escort the truck back to the weigh station or use a mobile scale to weigh the truck. Experts were asked where they might support the use of such a system (i.e., truck-only routes, alternative routes used to avoid inspection stations, rural roads, urban high volume roads, ports and, bridges).

The second scenario involved a fully-automated system designed to collect data on truck violations by capturing images of vehicle license plates. More specifically, a fully-automated system would be equipped with weight sensors and license plate image capturing technology. When an overweight truck drives over the weight sensor in the roadway, the camera is triggered and captures a photograph of the vehicle's license plate. This information could be used to monitor and track violators and allow for more targeted inspections and automated issuing of tickets). Experts were also asked where they might support the use of such a system (i.e., truck-only routes, alternative routes used to avoid inspection stations, rural roads, urban high-volume roads, ports and bridges).

Overall, stakeholders support the use of semi-automated systems with on officer present and few supported a fully-automated system:

- Several representatives from Caltrans and the CHP support the use of semi-automated systems, which use a VWS system combined with an officer. They believe this would be an effective tool in all locations. Experts stated that using a fully automated system is a big financial investment and they do not know if the state is ready to move in that direction yet.
- Some vendors support the use of VWS systems that use weight sensors placed in roadways with a wireless connection to an officer's laptop computer, which allows the officer to intercept overweight trucks.
- Some trucking companies support the use of VWS technologies if an officer is present but do not support the use of fully automated systems.
- Ports support the use of both semi-automated and fully-unmanned units but prefer a combination of both. They believe that due to the number of trucks currently on the roadways, unmanned units may be deployed sometime in the future but feel that having an officer dispatched to intercept a suspected violator would be easier to implement.
- One vendor supports the deployment of fully automated VWS systems and feels that this would allow for maximum screening and enforcement.

Experts were then asked to explain (their/their organization's) views on creating a national standard for the color and placement of commercial vehicle license plates and DOT numbers (i.e., an amendment to the vehicle code mandating that all commercial vehicle license plates have a white background and be located in the front and center of the truck bumper and all DOT numbers be placed on the front bumper as well). In general, the experts supported the standardization of license plate placement, color, and font as well as DOT number placement, color, and font:

- Representatives from Caltrans and technology vendors support standardizing the placement, font, and color of commercial vehicle license plates as well as mandating that all DOT numbers are placed in a location where they are clearly visible.
- The trucking company, interviewed as part of this evaluation, would like to see a national standard for both commercial vehicle license plates and DOT numbers. He supports this standardization because he believes it will enable trucks and goods movements to be tracked more efficiently.
- Ports support creating national standards for the placement, color, and font of commercial vehicle license plates and DOT numbers, and believe uniformity will allow for better tracking and enforcement.
- FMCSA believes that national legislation should be passed to regulate DOT numbers (i.e., color, size, font and placement) and link DOT numbers to Vehicle Identification Numbers (VIN). FMCSA feels that this would allow inspection/enforcement agencies to track trucks and regulate violators more effectively. However, FMCSA believes that it would be virtually impossible to create any type of national standard for commercial vehicle license plates due to state laws.

3.4 Sources of Support and Opposition to VWS

Finally, experts were asked where they thought the major support and opposition to VWS lies and why:

- Many representatives from Caltrans believe that the CHP would oppose the deployment of any VWS system due to concerns about job security.
- The CHP representative thought that commercial vehicle inspections officers would support the use of VWS technologies but "the higher ups at CHP would oppose it" because they are resistant to change and are upset about maintenance of current CVEF and WIM sites.
- Vendors thought that trucking companies would oppose the use of VWS technologies because trucking companies want to avoid inspection sites.
- Trucking companies thought that small owner-operated truckers would oppose the use of VWS technologies because they want to avoid inspections and that CHP would support these technologies because it would streamline the inspection process.
- The Ports believe that all ports and the CHP will support the use of VWS applications to identify overweight trucks and prevent roadway and structural damage, and that owner-operated truckers will oppose this technology because it can be used to identify violators.

3.5 Conclusions

The expert/stakeholder interviews have enabled researchers to gain background and understanding in several key areas related to the capacity and performance of the current commercial vehicle inspection process here in California, and to explore opinions about various potential virtual weigh station applications.

4.0 TECHNOLOGY ASSESSMENT

4.1 Weigh-in-Motion Technologies

Currently, three types of WIM systems are available for commercial use. These are based on the following technologies: Piezoelectric, Bending Plate and Load Cell. The difference between the three technologies lies in the relative accuracies and installation and operational costs. While the load cells are more accurate they are much costlier than their lower accuracy counterpart, piezoelectric sensors. Bending plate lies midway both in terms of accuracy and cost. (See Figure 5 below) See Appendix A for a detailed discussion of WIM technologies.

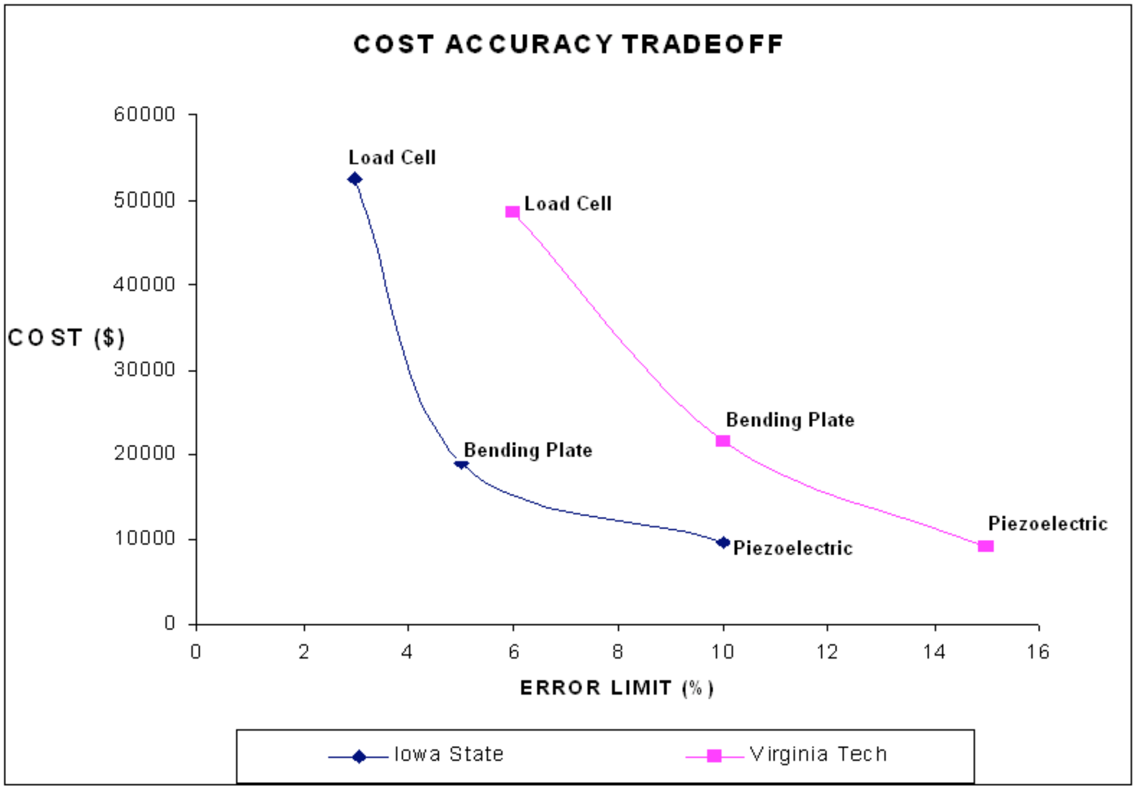


Figure 5. Cost Accuracy Tradeoff for the WIM Systems. (reproduced from http://www.ctre.iastate.edu/Research/wim_pdf/Secti3.pdf and http://ntl.bts.gov/lib/23000/23500/23532/WIM-Evaluation-FINAL-REPORT.pdf)

4.2 Weigh-in-Motion Applications

The three major WIM deployment efforts, in Maine, Kentucky, and Montana, were found in the literature. See Appendix A for a detailed discussion of WIM technology applications. The following is a description and evaluation of the applications.
In Maine, the department of transportation recently installed 12 WIM sensors at various strategic locations around the state. The system is used to capture and visually represent the data is known as JOHO. JOHO data are available on-line [http://www.americanimage.com/wimcount.htm]. The JOHO images are used to monitor the operation of the sensors. Loss of a sensor is immediately obvious when a JOHO image is updated. Some of the images generated by JOHO include: count by vehicle type, total vehicle count, overweight vehicle count, percentage overweight vehicle count, and vehicle speed distributions. This new method of representing WIM data appears to be efficient and much information is conveyed at a glance. The data from the functional WIM sites is not used for any sort of enforcement.

The operational test project along I-75 was a first step to experimentally determine fuel and time savings by allowing by-pass of weighing stations by electronically cleared vehicles. Tests conducted on the collected data suggest statistically significant fuel and time saving if automated clearance stations are used to electronically screen vehicles. This project was a joint effort by several states, government organizations, universities and industrial associations with the Kentucky Transportation department as the lead agency. Three types of WIM were tested, static scale, ramp WIM, and high speed ramp WIM. Savings were found to increase in this order: static scale, ramp WIM, and high speed ramp WIM. With growth in truck population and the inability of existing weighing stations to cope up with the demand, Virtual Weight Stations (VWS) that could allow automatic clearance of vehicles appears to be a promising alternative.

The Montana DOT State Truck Activities Reporting System (STARS) program uses data collected from WIM sites over time to direct future enforcements efforts. The evaluation of the program indicated a 22 percent decrease in percentage of overweight vehicles in traffic stream, a 16 percent decrease in the average amount of overweight vehicles, and a $0.7 million decrease in predicted pavement reconstruction cost. This program however, made an indirect (non real time) use of WIM data in the enforcements. A direct (real time) use of WIM data could lead to more efficient enforcements, but would first have to demonstrate sufficient WIM accuracy.

4.3 Safety, Security, and Air Quality Technology

The safety, security, and air quality technology is documented in Appendix G. The following are key findings of the review:

- The Oregon Greenlight transponders can now be used at PrePass™ clearance stations.
- License Plate Readers (LPRs) have a character recognition rate of 50 percent at highway speeds, but are only able to capture 60.2 percent of the traffic.
- Brake screening systems (IRISystem and Raytheon NightSight Protect IR4000B System) cannot be used at highway speeds, but can used at slower speeds (max 30-40 mph and average 10 mph) by experience operators to detect 68 to 77 percent of defective breaks.
- Remote Sensing Devices (RSD) are limited to single-lane implementation.

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APPENDIX A

Non-Compliance and Pavement Damage: Weigh-in-Motion Technology and Functionality

PATH TO 6105

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1: PROJECT INTRODUCTION AND REPORT ORGANIZATION

1.1 Introduction

The purpose of this project is to study recent developments in the use of Weigh–in-Motion (WIM) systems, Automatic Vehicle Identification (AVI) systems and other technologies to propose automated Virtual Weigh Stations (VWS). This will ensure better compliance of commercial vehicle operators and help reduce pavement damage and associated costs. This report is based on a literature review of numerous efforts across the U.S. to address these issues. It further discusses the existing WIM stations in California as of 2002 and their associated data.

1.2 Report Organization

This report is organized as follows:
Section 2 introduces the main types of Weigh-in-Motion (WIM) systems currently used. It briefly describes the key features of these systems and compares them based on cost and effectiveness;

Section 3 reviews some of the work previously accomplished using WIM in the U.S. Section 3.1 discusses new methods of data representation collected by WIM, which were developed by the Maine DOT. Section 3.2 discusses tests conducted on the I-75 Corridor to evaluate the benefits of electronic clearance systems and WIM equipment. Section 3.2 presents the STARS program implemented by the Montana DOT;

In Section 4 we look at the location and nature of data available from the existing WIM stations in California as of 2002. This is based on the report "Truck Traffic Analysis Using Weigh-In-Motion (WIM) Data in California" by Harvey et al. (2002).

2: WIM TECHNOLOGIES

This section discusses the three main types of Weigh-in-Motion (WIM) systems currently used:, piezoelectric sensors, bending plate sensors and those based on load cells. Sections 2.1, 2.2 and 2.3 describe the design, layout and salient features of each WIM system. Section 2.4 outlines some common features of these systems. Section 2.5 makes a comparison between these systems based on cost and effectiveness, determined by recent studies conducted by Iowa State and Virginia Tech Universities. Section 2.6 gives a summary of this Section.

2.1 Bending Plate Sensors

Bending plate sensors consist of plates with strain gauges bonded to the underside. As the vehicle passes over the plate, the strain is measured by the strain gauges to estimate the dynamic load. Static load (the load when the truck is at rest) is then determined from dynamic load using calibration parameters, incorporating vehicle speed and suspension/pavement dynamics. The setup for Bending Plate sensors typically consists of 1-2 scales placed in the travel lane perpendicular to the direction of travel (as shown in

Fig 2.1). This layout is also used for load cell sensors described in Section 2.3. It is common practice to place one scale in each wheel path of the traffic lane so that the left and right wheels can be weighed individually (Iowa State University 1997).

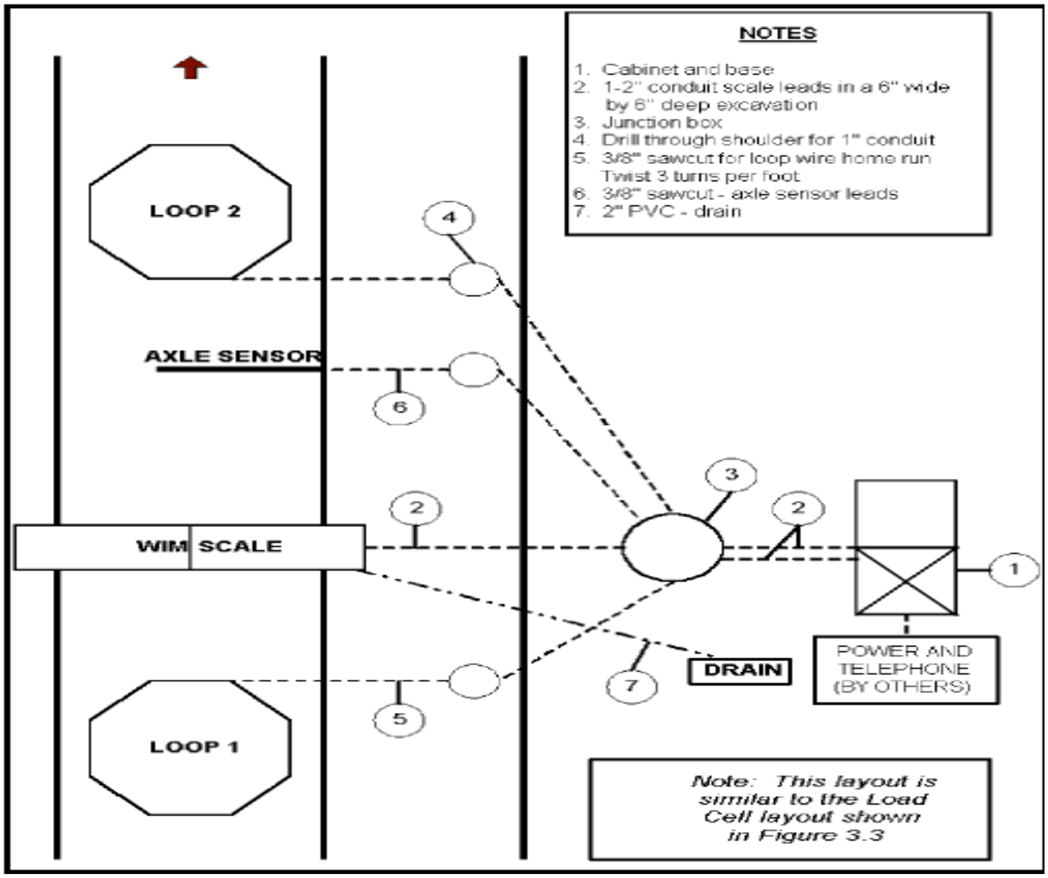

Fig 2.1 Typical Bending Plate and Load Cell Sensor Layout (Iowa State University 1997)

An additional axle sensor can be used to determine the speed of the vehicle by placing it downstream of the weigh-pad (Iowa State University 1997).
Two inductive loops are placed upstream and downstream of the WIM scale. This is done to ensure that the:

1. Upstream loop detects the vehicle presence and alerts the system of the approaching vehicle;
2. Vehicle speed can also be measured using the time it takes for the vehicle to move from the inductive loops to weigh-pad and vice versa.

2.2 Piezoelectric Sensors

This system uses piezoelectric sensors to detect a change in voltage, caused by pressure exerted on the sensor by an axle, and measures the axle's weight. As a vehicle passes over the piezoelectric sensor, the system records the electrical charge created by the sensor and calculates the dynamic load. The static load is estimated from the measured dynamic load using calibration parameters. Piezoelectric WIM systems are sometimes encapsulated in an epoxy-filled aluminum channel. The layout is shown in Fig 2.2 and is similar to the design layout for Bending Plate sensors and Load Cells shown in Fig 2.1.

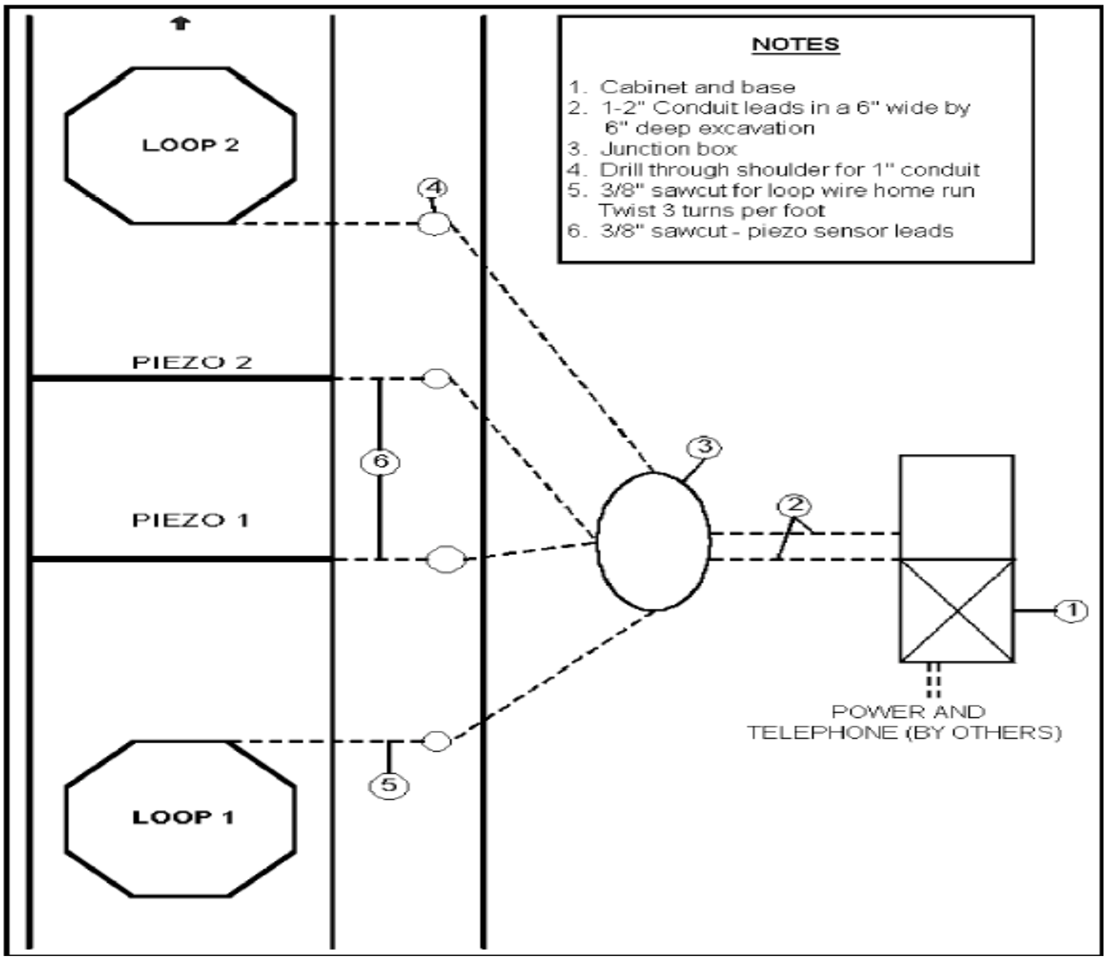

Fig 2.2 Typical Piezoelectric Sensor Layout (Iowa State University 1997)

2.3 Load Cell

A load cell is a transducer which converts a mechanical force (load) into a measurable electrical output. Load Cell WIM systems utilize a single load cell with two scales to detect an axle and weigh both the right and left side of the axle simultaneously. As the vehicle passes over the load cell, the system records the weights measured by each scale and sums them to obtain the axle weight. At least one inductive loop and one axle sensor is used. The layout and basic functioning is similar to that of bending plates. The difference is the quantity that is directly measured and the way in which it is measured. Figure 2.1 also gives the layout for the Load Cell.

2.4 Other Features

Listed below are some of the other characteristics common to all three types of WIM systems.

2.4.1 Processing Power
For all three WIM systems, the processing units sort and analyze the information obtained from sensors. Typically 15,000 trucks are processed per day and these systems can analyze 30 days of continuous data for 4 lane installations.

2.4.2 Operating Software
There are two types of software used by these systems: (1) on-site software and (2) communication and in-house software.

2.4.2.1 On-site software
This software interprets the signals from the WIM scales and generates the on-site files containing the following types of information:

1. Site identification
2. Time and date of passage
3. Lane number
4. Vehicle sequence number
5. Vehicle speed and classification
6. Weight of all axles or axle groups
7. Code for invalid measurement
8. Optional graphic configuration
9. Equivalent Single Axle Loading (ESAL) values

2.4.2.2 Communication Software and in-house software
This makes changes to the on-site software setup, including calibration factors from the in-house computer. It prepares hard copy reports and the ASCII files, which allows the user to typically perform the following operations:

1. Real time vehicle viewing selectable by lane
2. Resetting of the system clock
3. Monitoring system memory in terms of remaining storage
4. Setting up and initiating the generation of summary reports on data previously collected by the system
5. Viewing generated reports
6. Generating and viewing error reports including time down, system access, auto-calibration, and improperly completed records
7. Transferring selected raw data files or generated reports from the site system to the office host computer
8. Purging old data files from the system

2.4.3 Reporting
This is performed by the in-house software. It typically generates daily, weekly, monthly, or continuous summary reports in hourly increments based on the following:

1. Vehicle speed
2. Classification
3. ESAL
4. Weight summaries

Each of the above data can be generated by lane as well as by direction. Additionally, it generates reports on errors, auto-calibration, site history, calibration history, and overweight vehicles.

2.5 Comparison of Available WIM Technologies – Cost Accuracy Tradeoff

There have been some studies on the relative performance and cost associated with each type of system. Results from two such studies conducted by Iowa State University and Virginia Tech are shown in Tables 2.1 and 2.2 respectively. Fig 2.3 below shows the cost accuracy tradeoffs in choosing the three types of WIM systems.

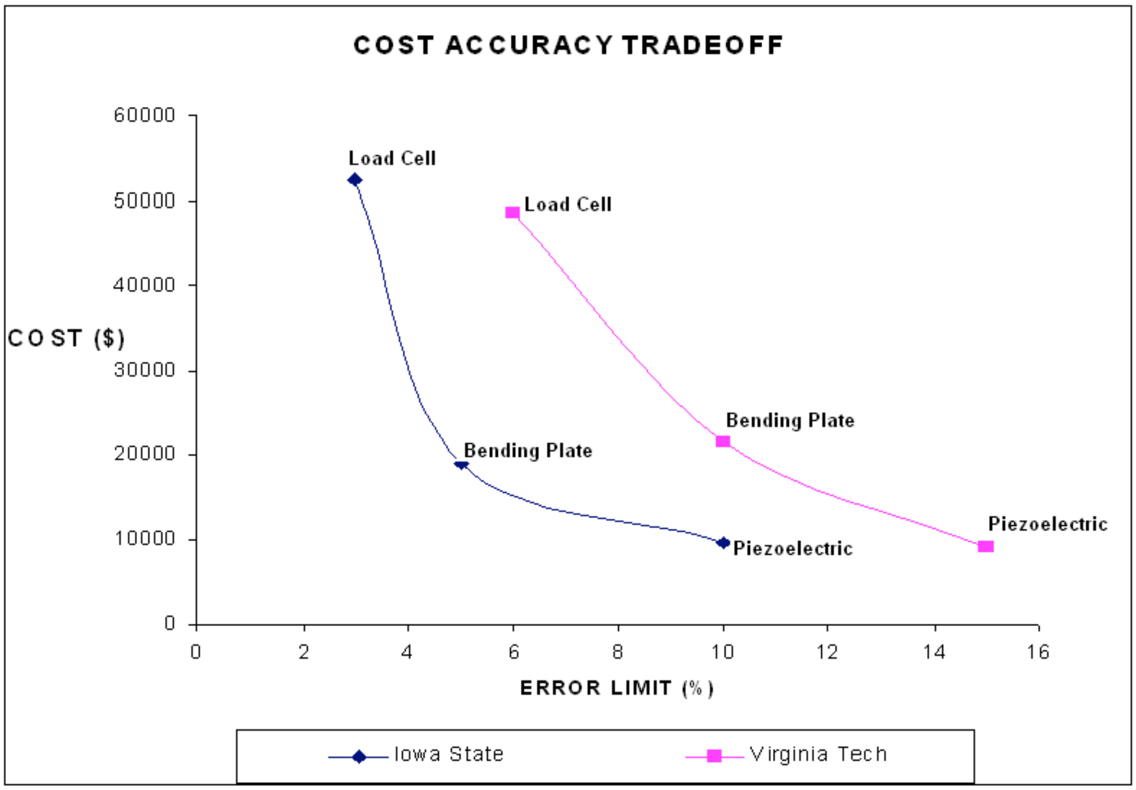

Fig 2.3 Cost Accuracy Tradeoff for the WIM Systems

The first study reports that the accuracy of measuring gross vehicle weights (weights before adjustments from speed, etc.) are within 10% for Piezoelectric Sensors, with estimated initial installation costs and subsequent maintenance costs to be $9500 and $4224 respectively (Table 2.1). The corresponding values of accuracies for Bending Plate sensors improve to 5% and to 3% for Load Cells. The initial cost of installation, however, doubles to $18900 for Bending Plates and almost sextuples ($52,500) for Load Cells. The long-term average maintenance cost, however, is not substantially different.

Table 2.1 WIM System Comparison Results (Iowa State University 1997)

WIM System	Performance (Percent error on GVW at highway speeds)	Estimated Initial Cost per Lane (Equipment and Installation)	Estimated Average Cost per Lane (12-year life span including maintenance)
Piezoelectric Sensor	+/- 10%	$ 9,500	$ 4,224
Bending Plate Scale	+/- 5%	$ 18,900	$ 4,990
Double Bending Plate Scale	+/- 3-5%	$ 35,700	$ 7,709
Deep Pit Load Cell	+/- 3%	$ 52,500	$ 7,296

Similar trends are reflected in the results of the second study conducted by Virginia Tech (Table 2.2) (Virginia Tech 2002). Accuracies improve from 15% to 10% to 6% and initial costs increase from $9000 to $21,500 to $48,000 when one moves from Piezoelectric to Bending Plate to Load Cell.

Table 2.2 WIM System Comparison Results (Virginia Tech 2002)

	Piezoelectric	Bending Plate	Single Load Cell
Accuracy (95% confidence)	± 15 %	± 10 %	± 6 %
Expected Life	4 Years	6 Years	12 Years
Initial Installation Cost	$9,000	$21,500	$48,700
Annual Life Cycle Cost	$4,750	$6,400	$8,300

Choosing among these options depends on the desired accuracy and budget.

2.6 Section Summary

Each of the three WIM systems - Piezoelectric, Bending Plate and Load Cell - has similar design layout and functionality. The difference lies in the relative accuracies and installation and operational costs. While the Load Cells are more accurate, they are much more expensive than their lower accuracy counterpart – Piezoelectric sensors. Bending Plate lies midway in terms of both accuracy and cost. It is a tradeoff and the final choice depends on the available budget and desired accuracy.

3: REVIEW OF OTHER STATES' PRACTICES

This section reviews some of the work already accomplished using weigh-in-motion (WIM) systems in different states. The first state discussed is Maine, where some new methods of data representation obtained from WIM stations are being evaluated. Next, the I-75 Corridor is studied, where several tests were conducted to evaluate the benefits of using electronic clearance systems and WIM equipment. Finally, we assess Montana's STARS program.

3.1 Maine DOT: Advanced Representation methods for WIM data

The Maine Department of Transportation has recently installed 12 weigh-in-motion (WIM) sensors at various strategic locations around the state. The system, which captures and represents the data, is called JOHO and is revolutionary in the way it represents information to the viewer (user) (American Image, Inc.). Maine DOT uses JOHO images to monitor the operation of the sensors. Loss of a sensor or a lane is immediately obvious when a JOHO image is updated. Below are some of the images generated by JOHO and a brief explanation of their advantages over the traditional methods of similar data representation. Typically it can represent data on the following:

1. Count by vehicle type
2. Total vehicle count
3. Overweight vehicle count
4. Percentage overweight vehicle count
5. Vehicle speed distributions

The images and brief explanations are provided in this section; further images can be found at the end of this report.

3.1.1 Count by Vehicle Type

Figure 3.1 represents the total number of southbound FHWA Type 11 (double trailer) trucks passing over a particular sensor on Interstate 95 in Kittery, Maine for every hour in 2001. The following grid representation scheme is used:

1. The columns represent the time of day – 12 A.M. to 11 P.M. from left to right.
2. The rows represent days of the month – 1 to 30/31 from top to bottom.

The count for each grid is indicated in the legend.

To demonstrate the amount of information conveyed by these images, we can interpret the following directly from Fig 3.1:

1. Most southbound traffic is from 8 P.M until midnight. This is because most trucks are heading south during the night carrying goods for the Boston metropolitan area,
2. There is less traffic on weekends,
3. There is little seasonal variation,
4. A 1 hour shift in pattern from October to November can be clearly discerned. This is because the sensor clock remained incorrectly set to daylight savings time,

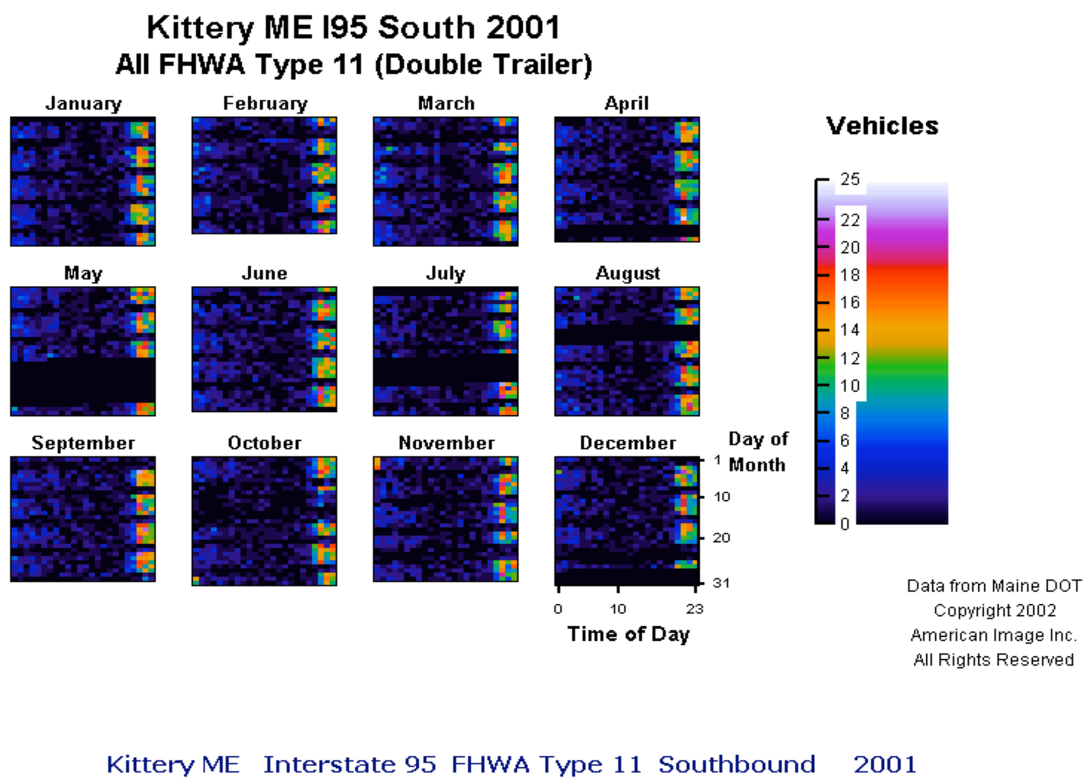

Fig 3.1 Total Number of Southbound FHWA Type 11 (double trailer) Trucks Passing Over a Sensor on Interstate 95 in Kittery, Maine for Every Hour in 2001 (American Image, Inc.)

3.1.2 Total Vehicle Count

The total vehicle counts for the month of November are provided in Fig 3.2. The image contains 720 data points. As before, we can interpret the following information from it:

1. People generally arrive in Maine for the weekend,
2. There is a consistent pattern across weekends – Friday, Saturday and Sunday show higher volumes of traffic,
3. The variant traffic behavior on the Thanksgiving weekend can be seen here. We observe heavy traffic volume on Wednesday afternoon. On Thanksgiving Day (Thursday), traffic drops suddenly at noon. Sunday traffic picks up again as people return.

The purpose of this brief description was to highlight the significant amount of information that this powerful method of representation can convey in a single glance. Few other images have been provided after the report for further investigation. However, the basic grid pattern of representation of counts is the same in all the images.

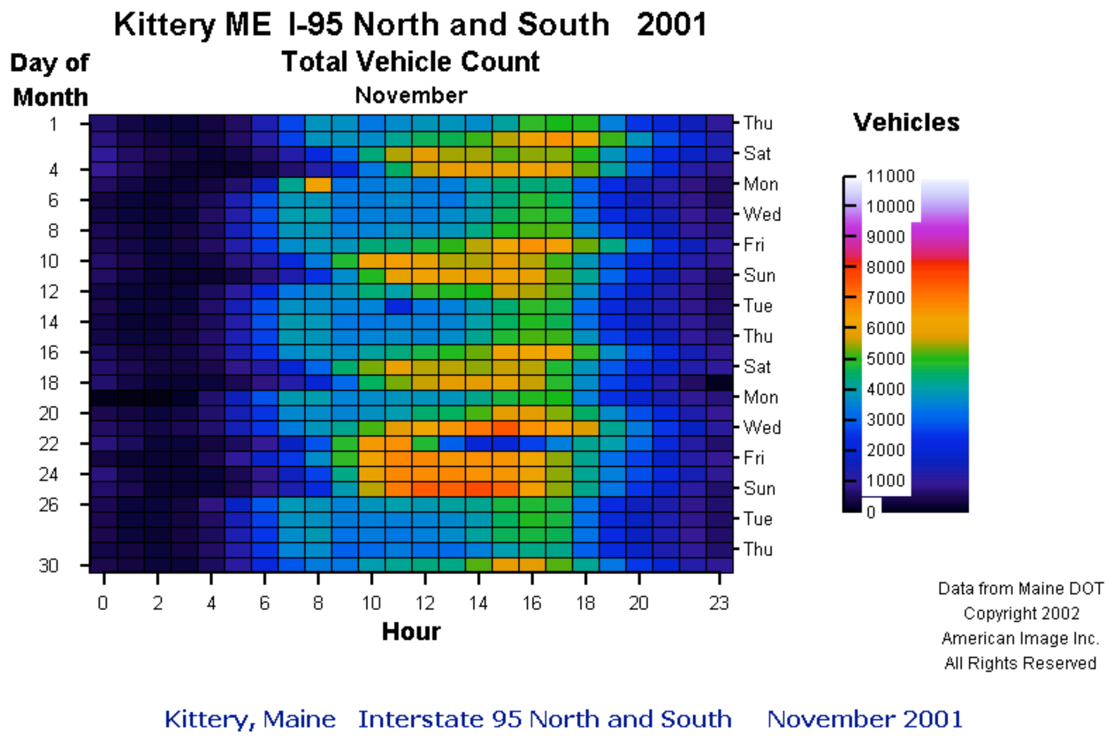

Fig 3.2 Total Vehicle Count for Kittery, Maine for November 2001 (American Image, Inc.)

3.1.3 Summary

In Fig 3.1 and 3.2, two types of counts were displayed. It should be noted that apart from this, JOHO images also captures the overweight vehicle count, percentage overweight vehicle count and vehicle speed distributions (referenced after the report). The new method of representation of WIM data appears to be more efficient and much information is conveyed at a glance. However, Maine DOT is still to utilize the data from the functional WIM sites for any sort of enforcement. A study on accuracies of such sophisticated images is another issue that needs to be conducted.

3.2 Advantage I-75 Operational Test Project

3.2.1 Introduction

The operational test project along I-75 was a first step to experimentally determine fuel and time savings by allowing the by-pass of weigh stations by *electronically cleared* vehicles. Tests conducted on the collected data suggest statistically significant fuel and time savings if automated clearance stations are used to electronically screen vehicles. The results of this project favor the move towards Virtual Weigh Stations (VWS) and Automated Electronic Clearance Systems.
It should be noted that this project was a joint effort by several states, government organizations, universities and industrial associations with the Kentucky Department of Transportation as the lead agency.

3.2.2 Goals of the Project

The following goals were identified at the start of this project by the team:

1. To allow transponder-equipped and properly documented trucks to travel the entire length of I-75 along mainline, with no more than one stop at weigh stations to verify weight compliance and credential status,
2. To develop Mainline Automated Clearance System (MACS), a commercial vehicle electronic clearance system,
3. To operate for 2 years, October 1995 through September 1997, and conduct tests to evaluate benefits.

3.2.3 Methodology:

First, a pilot study was conducted through September 1995. This provided the basis for the actual tests in test period 1995-1999, with regard to the types of tests, number of sample data and methods to evaluate different parameters. Trucks enrolled in the test program were equipped with a transponder (i.e., two-way communication device mounted on the windshield). This transponder can communicate with the roadside equipment to allow a central system to identify the truck and check its credentials. Weight information was obtained in one of the following two ways:

1. Weight data stored in transponder from earlier weighing in the trip
2. New measurement from WIM equipment

If the weight was within a specified range and the credentials were found to be valid, a pre-clearance signal was sent to the transponder, which resulted in a flashing green light and audio signal inside the truck, indicating to the driver to bypass the station.

Along I-75 and 401-Corridor, a total of approximately 4500 trucks were equipped with transponders. In all, 29 weigh stations had AVI reader capability. As pointed out earlier, the approach adopted was to install and operate prototype system at selected weigh stations along the corridor and to conduct studies and evaluate the benefits.

3.2.4. Test 1: Fuel Savings Due To Elimination/Reduction of Stops

The first test conducted was to determine whether reduction or elimination of stops at weigh stations by participant transponder-equipped trucks would result in measurable energy (fuel) savings for each equipped truck. The test was conducted according to the Society of Automotive Engineers' (SAE) guidelines (Crabtree 1995).

The prescribed method directed one truck to stay on the mainline and a second truck to enter the weigh station. The second truck would then either stop or slow at the scale, depending on the design of the weigh station. The fuel used by each truck was then precisely measured to determine the fuel used by each vehicle. The difference in fuel used was the estimated savings of fuel attributable to a truck bypassing a weigh station. Identical trucks, the same load and the respective same driver, were employed for each run. Fifteen-gallon fuel tanks were used in each truck. Tests were run with the weigh stations closed in order to control the variability of fuel consumption associated with queues.

The test was conducted in the following way:

1. Two trucks were used; one was called the control truck and the other was termed the test truck.
2. Two kinds of runs were completed:
    a. Run type 1, when both the control truck and test truck bypassed the weigh station. The baseline fuel consumption difference was estimated as the difference between the fuel consumptions of the two trucks.
    b. Run type 2, when the control truck bypassed the weigh station at mainline speed and the test truck slowed down or stopped at the weigh station (according to weighing requirements at that station). This gave a measure of the experimental fuel consumption difference.
3. Run types 1 and 2 were repeated a fixed number of times depending on the weigh station being evaluated.
4. Fuel savings were estimated using the difference between the baseline fuel consumption difference and the experimental fuel consumption difference. (Crabtree 1995)

A typical test route is shown below in Fig 3.3

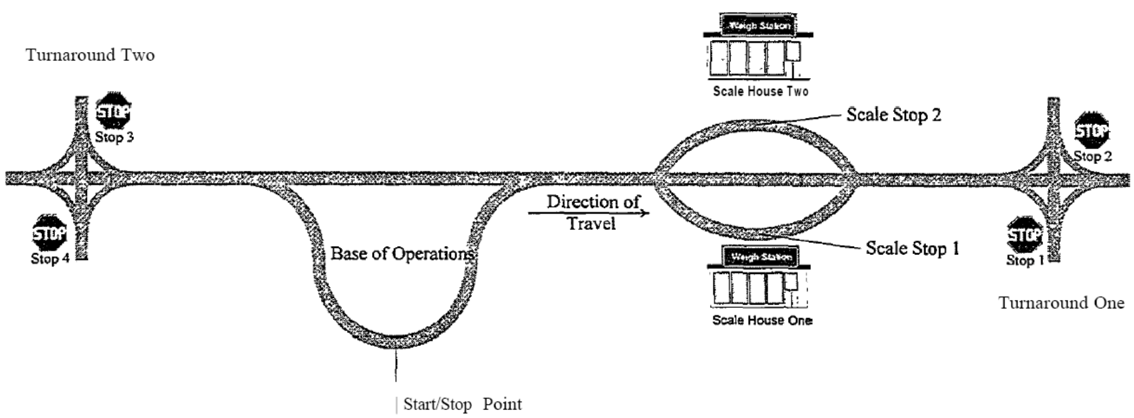

Fig 3.3 Typical Test Route

As seen in the figure, an area was specified as the base of operations. This was where necessary supplementary activities like installing and removing tanks and refueling were carried out. For selection of test locations, the first priority was to have representation of all three types of weigh stations; specifically, Static Scale, Ramp WIM and High Speed Ramp WIM. Another important consideration was the diversity of terrain. The most favorable and least favorable topographical conditions for each weigh station design type were used to choose weigh stations of each type for evaluation.
The normal Static Scale is shown in Fig 3.4. All trucks entering the weigh station are directed to the static scales. The setup for Ramp WIM station is shown in Fig 3.5 and allowed credentialed bypass at up to 35mph. A High Speed Ramp WIM is shown in Fig 3.6 and allowed trucks to use bypass lanes at speeds up to 45mph. The presence of two static scales doubled the service rate and decreased the average waiting time in queue for trucks.

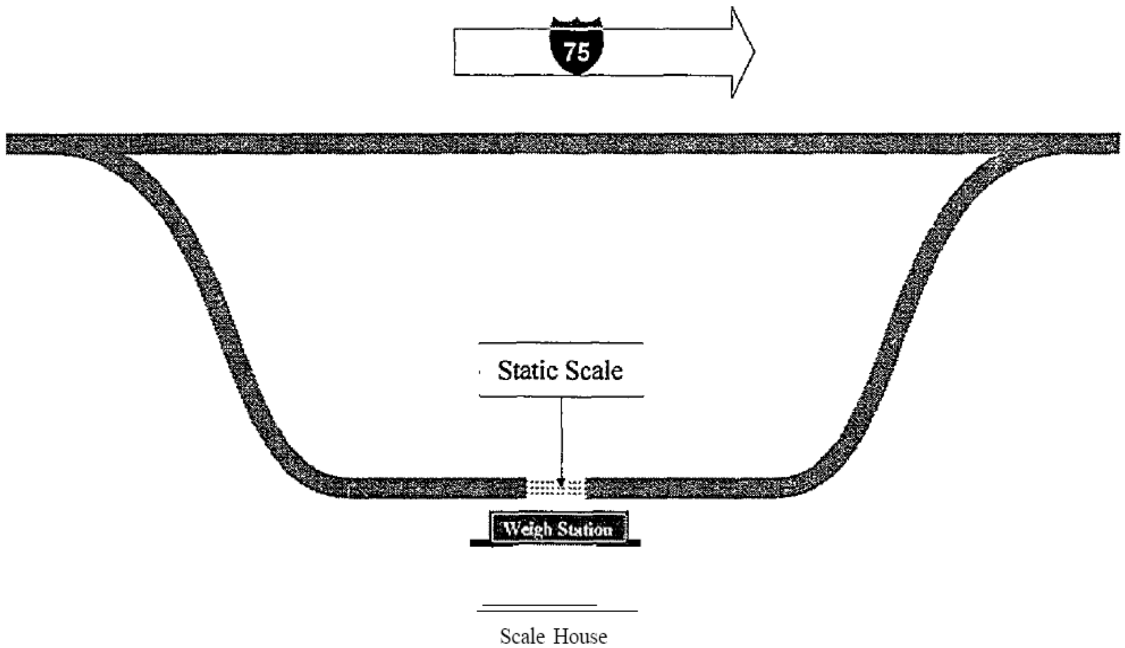

Fig 3.4 Single Static Scale Weigh Station – All trucks that enter station are directed to static scales.

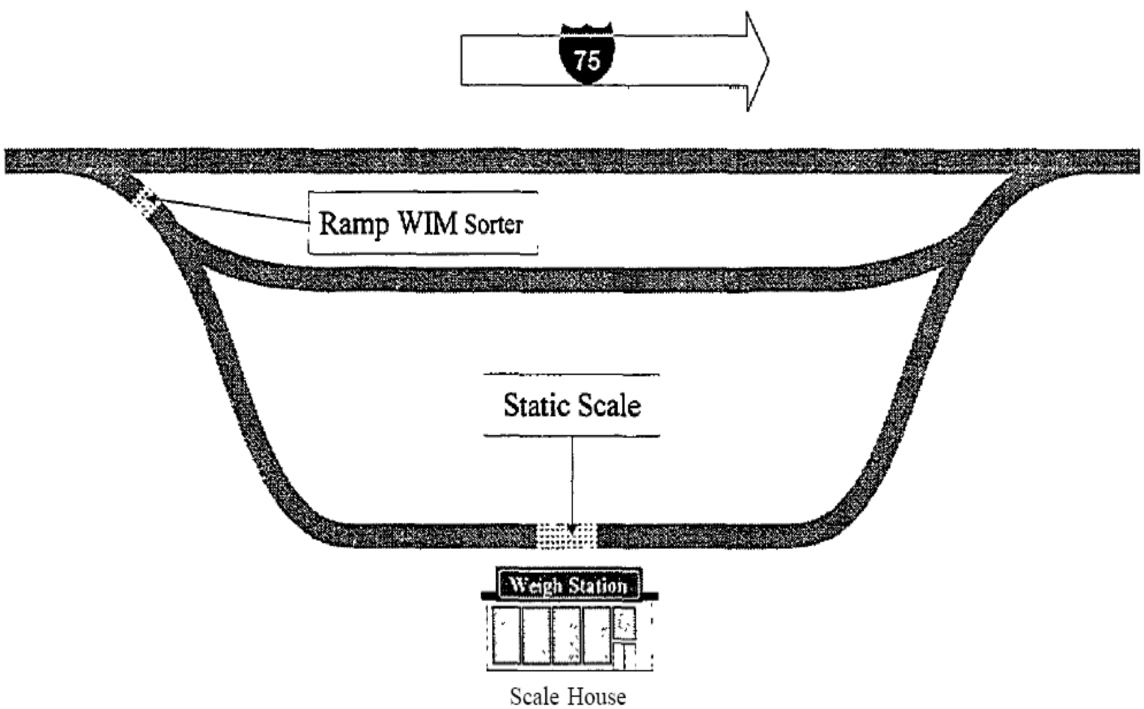

Fig 3.5 Ramp WIM Single Bypass Lane

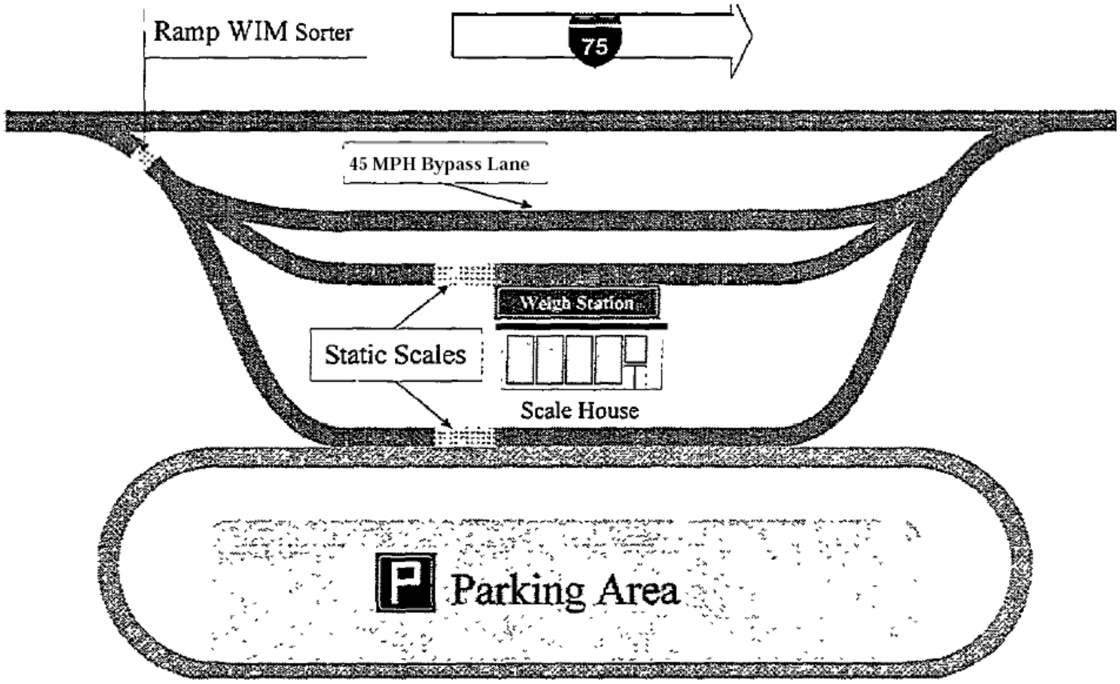

Fig 3.6 High Speed Ramp WIM with 2 Static Scales

The pilot study had recommended the use of 60 runs (30 control runs and 30 test runs) for the static scales, 100 runs for RAMP WIM Scales and 140 runs for High Speed Ramp WIM scales. However, based on the variability of the data from the first few runs and the time constraint, the number of tests in each category was reduced by half. The details for the test location are shown in Table 3.1.

Table 3.1 Test Location, Design Type and Durations

Test Location	Design Type	[Duration (in Days)	Total Test Runs
Monroe, MI	Ramp WIM	7 Days	50
Findlay, OH	Static Scale	5 Days	30
Knoxville, TN	Static Scale	5 Days	30
Monroe Co., GA	Ramp WIM	7 Days	50
Charlotte Co., FL	High Speed Ramp WIM	9 Days	70

The results for the tests are shown below in Table 3.2. Both the mean values of savings and the values at the 95% confidence interval range are listed. It is evident that bypassing the Static Scales provide the highest fuel savings and bypassing the High Speed Ramp WIM stations provide the least fuel savings. This is expected given the lower service rate of static scales.

Table 3.2 Fuel Saving Results

Location	Weigh Station Type	Estimated Fuel Savings in Gallons (Liters)	95% Confidence Interval in Gallons (Liters)
Monroe MI	Ramp WIM	0.11 (0.42)	0.085, 0.134 (0.322, 0.507)
Findlay OH	Static Scale	0.18 (0.68)	0.151, 0.207 (0.572, 0.783)
Knoxville TN	Static Scale	0.16 (0.61)	0.134, 0.194 (0.507, 0.734)
Monroe Co. GA	Ramp WIM	0.06 (0.22)	0.026, 0.097 (0.098, 0.367)
Charlotte Co. FL	High Speed Ramp WIM	0.05 (0.19)	0.037, 0.067 (0.140, 0.254)

3.2.5 Fuel Savings Due to Elimination/Reduction of Queues

The goal of these tests was to estimate the fuel wasted from the regular stop and go in the slow moving queues formed outside the weigh stations. These tests were conducted in the large parking and inspection area at the Charlotte County, Florida weigh station (Fig 3.7). Like the earlier fuel savings tests, two types of trucks were used – control and test trucks.

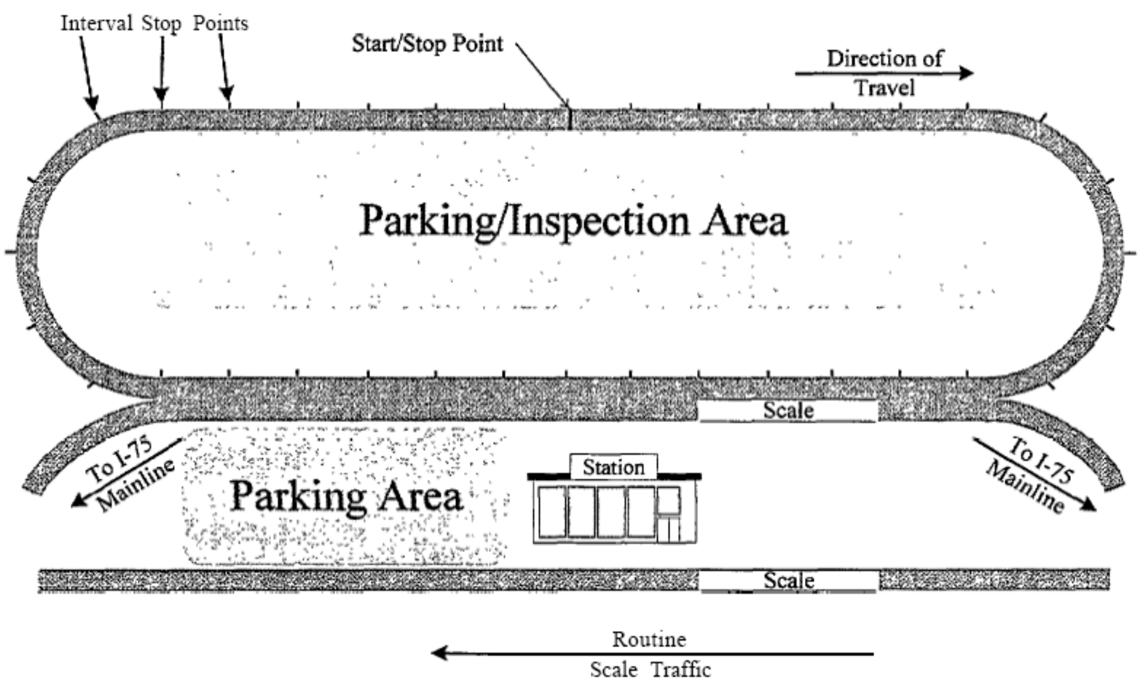

Fig 3.7 Queue Fuel Consumption Test

Three different types of runs were conducted:

1. Baseline runs, to establish the baseline fuel consumption differences between the control and test trucks. In these runs neither truck made any stops. Five baseline runs were conducted.
2. Experimental Type 1 – The control truck made no stops while the test truck stopped every 200 feet. Five such runs were conducted.
3. Experimental Type 2 – The control truck made no stops while the test truck stopped every 100 feet. Five such runs were conducted.

The results for these tests are shown in Table 3.3. A negative sign indicates savings. The average fuel savings of no stopping was highest relative to stopping when the distance between successive stops decreased from 200 to 100 feet.

Table 3.3 Queue Fuel Consumption Test Results

Run Type	**Approx. stops** ft. (m)	**Approx. Speed in** mph (kph)	**Number of Runs**	**Mean** in Gal. (Ltr.)	**Standard Dev.** in Gal. (Ltr.)	**SE Mean** in Gal. (Ltr.)
Baseline	None	13.1 (21.1)	5	0.0697 (0.263)	0.0124 (0.047)	0.0055 (0.021)
Experimental I	200' (61 m)	3.8 (6.1)	5	-0.1897 (-0.718)	0.0127 (0.048)	0.0057 (0.022)
Experimental II	100' (30.5 m)	2.3 (3.7)	5	-0.2960 (-1.120)	0.0233 (0.088)	0.0104 (0.039)

3.2.6 Travel Time Benefits

In this series of tests the estimated travel time savings was estimated. This was done by comparing the travel time difference between trucks which go through the normal inspection process at weighing station and trucks that are allowed to bypass the weigh station at mainline speed by virtue of the advanced clearance system. The experiments were conducted in the following way:

Recorders (two research assistants equipped with stop watches) were placed at three points (as shown in Fig 3.8).

1. Point 1 - Entrance point of weigh station
2. Point 2 - At the static scale located at the center of the weigh station
3. Point 3 - Exit point of weigh station

Each research assistant recorded the exact time the truck crossed the point. This test was conducted at 19 weigh stations (Table 3.4), representing all three types (i.e., static scale, ramp WIM and high-speed ramp WIM).

The two research assistants manually recorded the vehicle identification data and noted the crossing times (using stop watches) at each of the three points.

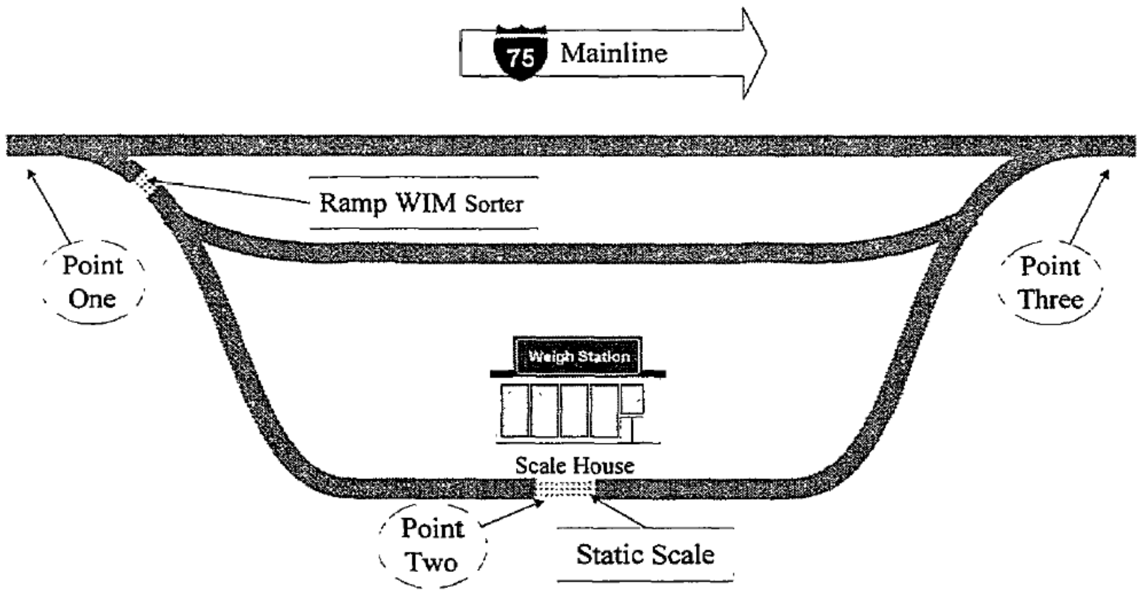

Fig 3.8 Data Collection Points

Based on the results of the pilot study, it was initially decided to collect data at a stretch for 66 minutes. This was based on the fact that six extra minutes allowed the last vehicle entering after 60 minutes from the start of the test to clear the weigh station comfortably. However, the data were finally collected over two-hour periods.

The two main quantities estimated were as follows:

1. Inter-arrival time, or the mean headway between vehicles arriving at point 1
2. Processing time, or the difference in times noted at points 3 and 1 for the same vehicle

The mainline travel time was calculated between points 1 and 3, based on sample data from trucks that bypassed the stations at mainline speeds. The difference gave the time savings.

Three different inspection scenarios were considered as follows:

1. Stop at scale: The routine processing in which the truck was directed to the static scale, weighed and then exited.
2. Level 1 Inspection: This was a brief inspection; the vehicle was directed to park on the scale itself, followed by a brief credential checking and subsequent release.
3. Level 2 Inspection: This was a detailed inspection in which the subject vehicle was pulled out of queue, required to park at a point and subsequent detailed credential checking was conducted.

Table 3.4 Weigh Station Choice for Time Savings Estimation

Station Name	Design Type	Peak Hours	Peak Queue Conditions
Halton, ON	Ramp WIM	7:00-9:00 AM East 9:00-11:00 AM & 3:00-5:00 PM West	Frequently full queues resulting in manual closing as frequently as 6 times/hour during peak periods.
Middlesex, ON	Ramp WIM	7:00AM-3:00PM East 7:00-9:00 AM & 1:00-3:00 PM West	Frequently full queues resulting in automatic station closing as frequently as 3 times/hour during peak periods.
Essex,ON	Ramp WIM: East Static Scale: West	7:00AM-3:00PM East 7:00-10:00AM West	Frequently full queues resulting in automatic station closing as frequently as 6 times/hour during peak periods.
Monroe, MI	Ramp WIM	6:00-9:00 AM North 3:00-6:00 PM South	Frequently 2,000 ft queues during peak hours. No station closings.
Wood, OH	Static Scale	5:00-9:00 AM & 2:00-7:00 PM	Queue overflows onto mainline 5-7 times per hour during peaks. Manual station closing when notified by CB radio.
Hancock, OH	Static Scale	6:00-9:00 AM & 3:00-6:00 PM	Queue overflows onto mainline 7-9 times per hour during peaks. Queue monitored by TV camera. Manual station closing when queue fills.
Kenton, KY (southbound only)	Ramp WIM	9:00-11:00 AM	Rarely full queues. No station closings.
Scott, KY (northbound only)	Ramp WIM	6:00-9:00 AM & 3:00-6:00 PM	Rarely full queues. Automatic station closing when queue fills.
Knox, TN	Static Scale	6:00AM-5:00 PM	Consistently full queues. Vehicles instructed to bypass when full. No station closings.
Monroe, GA	Ramp WIM	11:00 AM-4:00 PM	Seldom full queues. Manual station closing when full.
Lowndes, GA	Ramp WIM	7:00-11:00 PM South 9:00 AM-4:00 PM North	Seldom full queues. Manual station closing when full.
Charlotte, FL	High-Speed Ramp WIM	10:00 AM-5:00 PM	No full queues. No station closings.

At WIM stations all vehicles do not go to Static Scale. The frequency of this occurrence was also determined from the data.
The results for these tests are shown for the Static Scale, Ramp WIM and High Speed Ramp WIM stations in Tables 3.2.5, 3.2.6 and 3.2.7 respectively.

Table 3.5 Travel Time Savings at Static Scale Type Weigh Stations

Station	N	Mean Processing Time (Sec.)	Std. Dev (Sec.)	Mainline Travel Time (Sec.) [1]	Estimated Time Savings (Sec.)
Wood OH NB	1,246	137.5	44.68	31.82	105.7
Hancock OH SB	1,312	128.04	39.45	31.86	96.18
Knox TN NB	454	295.68	70.15	37.76	257.92
Knox TN SB	457	287.09	75.38	37.76	249.33
Essex, ON WB	794	150.17	81.59	15.92	134.25

[1] Ohio speed limits for commercial vehicles is 55 mph (88 kph). Other states are 65 mph (105 kph).

Table 3.6 Travel Time Savings at Ramp WIM Type Weigh Stations

Station	N	Mean Processing Time (Sec.)	Std. Dev. (Sec.)	Mainline Travel Time (Sec.)[1]	Estimated Time Savings (Sec.)
Halton ON EB	567	173.93	142.47	31.92	142.01
Halton ON WB	845	150.84	158.31	30.99	119.85
Middlesex ON EB	1,895	116.13	56.79	50.35	65.78
Middlesex ON WB	1,734	118.63	48.43	47.68	70.95
Essex ON EB	1,055	149.27	58.43	31.37	117.9
Monroe MI NB	1,990	78.33	30.24	42.01	36.32
Monroe MI SB	1,892	81.35	48.72	30.99	50.36
Scott KY NB	1,351	96.53	43.93	26.93	69.6
Kenton KY SB	992	162.06	160.17	51.48	110.58
Monroe GA SB	1,392	104.32	51.5	32.89	71.43
Lowndes GA NB	873	85.48	63.5	33.18	52.3
Lowndes GA SB	814	88.73	83.04	33.18	55.55

[1] Michigan speed limit for commercial vehicles is 55 mph. Other states' limits are 65 mph.

Table 3.7 Travel Time Savings at High Speed Ramp WIM Type Weigh Stations

Station	N	Mean Processing Time (Sec.)	Std. Dev. (Sec.)	Mainline Travel Time (Sec.)	Estimated Time Savings (Sec.)
Charlotte FL NB	800	97.59	49.06	47.94	49.65
Charlotte FL SB	799	132.85	82.55	47.98	84.87

As earlier, the highest bypass savings occur in the case of Static Scale weigh stations, followed by the Ramp WIM and then closely followed by the High Speed Ramp WIM. The order of savings per vehicle is significant in all three cases. Interestingly, for each vehicle these savings would accumulate across several sites as the truck is allowed to bypass the sites one after the other in series.

Other data collected is shown below in Table 3.8 and 3.2.9. Table 3.8 gives the frequency of the three types of inspection scenarios. Table 3.9 gives the percentage of vehicles for which credential checks and inspections are done at chosen weigh stations.

Table 3.8 Weigh Station Processing Scenarios

Location	N - Number of Trucks Through W.S.	Stop at Scale-Number (%)	Level One Inspections Number (%)	Level Two Inspections-Number (%)
Group One				
Halton, ON EB	609	260	18	0
Halton, ON WI3	909	384	4	8
Middlesex, ON EB	1,954	236	3	4
Middlesex, ON WB	1,793	202	6	6

Table 3.9 Percentage of Credential Checks and Vehicle Inspections at Weigh Stations

Weigh Station	% Stop at Scale	% Credential Check	% Inspection
Group One			
Halton ON EB	42.69	2.96	0
Halton ON WB	42.2	0.44	0.89
Middlesex ON EB	12.08	0.15	0.2
Middlesex ON WB	11.27	0.33	0.33

This data was extremely important in the simulation models developed by Ohio University, which were developed and validated using the data collected during this project.

3.2.7 Conclusions

This test program indicated significant time and fuel savings that can be achieved by allowing bypass of weighing stations electronically. These savings are increased in this order: Static Scale, RAMP WIM and High Speed RAMP WIM. With more trucks using the roadways and an inability of existing weighing stations to cope up with the demand, Virtual Weigh Stations (VWS) could allow automatic clearance for vehicles and appears to be a promising option.

3.3 Montana STARS Program

The following goals were identified by the Montana DOT when implementing the State Truck Activities Reporting System (STARS) program:

1. Improving the effectiveness of truck weight enforcement activities carried out by the Motor Carrier Services (MCS) division of the Montana Department of Transportation (MDT).
2. Providing MDT access to improved truck-related data for use in pavement design (Stephens and Carson 2003).

Instead of using data from WIM in real time, the STARS program used data collected from these WIM sites over a long period to direct future enforcements. The details will be provided in the following sections.

There was an estimated 22% decrease in percentage of overweight vehicles in traffic stream, 16% decrease in average amount of overweight vehicles and a $0.7 million decrease in predicted pavement reconstruction cost attributed to Montana's STARS program.

3.3.1 STARS – State Truck Activities Reporting System

STARS consists of 28 permanent and 62 intermittently operated WIM sites, the latter using fully portable WIM equipment. Out of these, only 4 are fully automated weigh stations using WIM and AVI systems to allow bypass for credentialed weight-compliant commercial vehicles.

In 2001, 19 permanent WIM sites were installed; 16 of these were fully functional. A certain number of mobile WIM stations were also active at this time. The remaining sites were developed after 2001.

3.3.2 Montana Highway System:

Montana has a total of approximately 11,705 miles of highway. Ninety-percent of commercial vehicle traffic in the state is jointly on:

1. Interstate highways
2. Non-interstate highways
3. Primary systems

Traditional weigh stations, as well as the STARS program, focused on these 3 categories. Table 3.10 shows the distribution of traffic on different types of highway systems in Montana in 2001.

Table 3.10 Montana Highway System - 2001

Highway System[a]	Centerline Miles	Daily VMT	
		All Vehicles	Commercial Vehicles[b]
Interstate	1,191	6,675,168	1,348,384
Non Interstate NHS	2,683	6,668,228	780,183
Primary	2,815	3,326,906	306,075
Secondary	4,698	1,977,647	185,899
Urban	382	2,287,417	98,359
State Highways	1,180		

[a] Local municipal and county roads not included

[b] Proportion of commercial vehicles estimated from Stephens and Menuez (2000)

3.3.3 Approach of Montana Carrier Services before STARS:

Motor Carriers Service (MCS) is the lead agency for truck size and weight enforcement in Montana. They employed the following two types of strategies conventionally:

1. Operate a network of permanently and intermittently staffed weigh stations with static scales.
2. Statewide Mobile Enforcement program: This was in operation since the mid-1990s, prior to the implementation of the STARS program. Individual officers worked out of their vehicles, stopped commercial vehicles and used portable weighing equipment to measure the weights of these vehicles.

Mobile enforcement officers traditionally devoted up to 70% of their time in random enforcement of local roads and highways not serviced by weigh stations. Each officer within his assigned area exercised discretion as to which roads to patrol and which types of vehicles to investigate. Thus the overall effectiveness depended on the officer's experience, knowledge of truck traffic patterns and enforcement intuition. There were some major drawbacks with this method, including:

1. There were no fixed guidelines or working methodology. Each officer did the enforcement in the way he or she thought was most effective, which may not always be the case.
2. New officers and staffing changes caused serious temporary ineffectiveness.
3. New officers experienced significant learning curves while developing the desired skills. Effective enforcement required knowledge of traffic truck patterns and a certain level of enforcement intuition. Acquiring these skills was generally a slow and tedious process.
4. It was virtually impossible for the managers at Montana Carrier Services to identify and correct non-productive activities.

All these drawbacks called for a more effective technological solution to this problem.

3.3.4 STARS: Selection of WIM locations

The first step was the selection of locations to install the WIM equipment; this was done based on the following factors:

1. The volume of commercial vehicle traffic carried on each route
2. The location of already existing weigh stations
3. Recommendation of Federal Highway Association's (FHWA's) Traffic Monitoring Guide – 2001

As weigh station coverage was highest on interstate systems, STARS mainly focused on non-interstate highways and primary routes in the state. It was further planned that portable sites would cover the less traveled routes known to seasonally experience heavy truck traffic.
The location of the permanently staffed weigh stations and STARS WIM sites is shown in Fig 3.9 and Table 3.11.

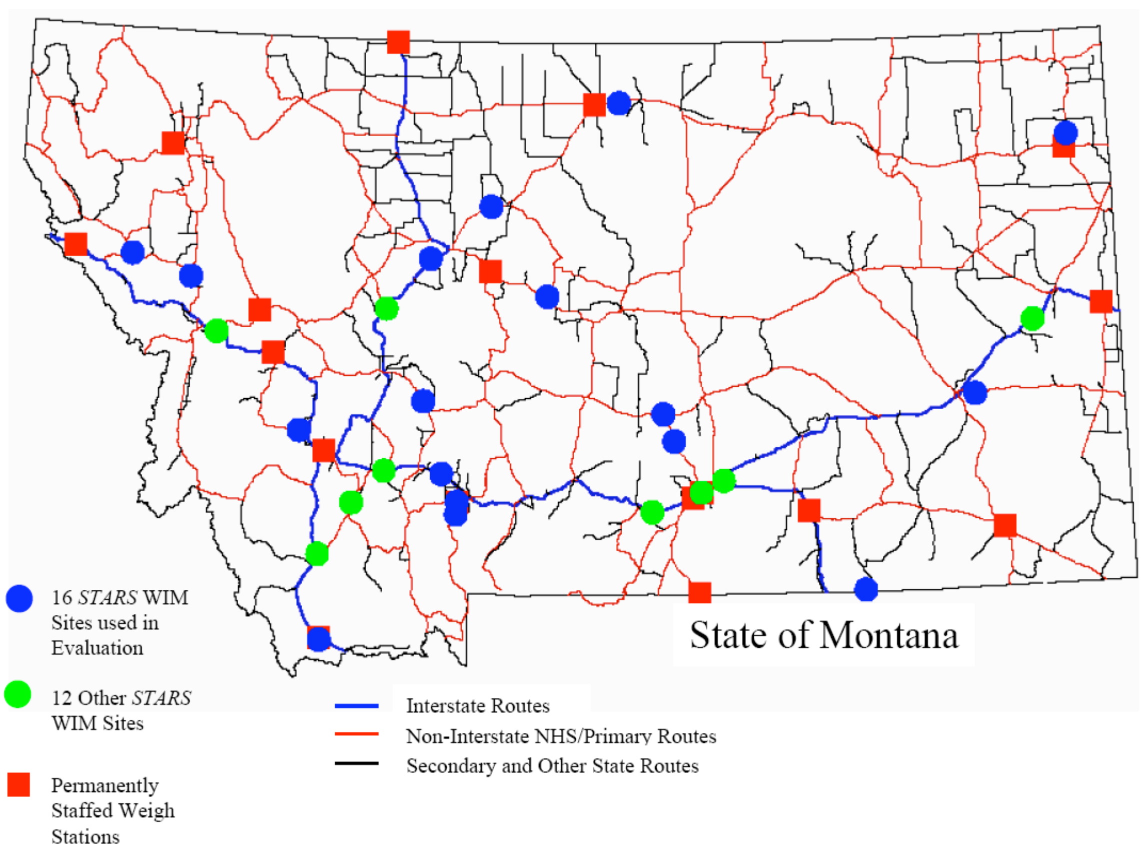

Fig 3.9 Montana State Highway – Weigh Stations and STAR Sites (Little 2003)

3.3.5 STARS: Components

1. Hardware: 25 out of 28 WIM sites used Piezoelectric WIM sensors while the remaining 3 employed Bending Plate WIM sensors. Details of both types of sensors have been discussed earlier in this report.
2. Software: MEARS (Measurement of Enforcement Activities Reporting System) computer software program developed by MDT, which automatically analyzes data collected in all WIM sites. A typical report by MEARS is shown in Table 3.11.

Table 3.11 WIM System Location and Equipment (2003)

Site	Highway System	Route	Technology
Townsend	Primary and Non Interstate NHS	U.S. Highway 287	Piezoelectric
Decker	Secondary	Highway 314	Piezoelectric
Bad Route	Interstate	Interstate 94	Piezoelectric
Manhattan	Interstate	Interstate 90	Piezoelectric
Arlee	Primary and Non Interstate NHS	US Highway 93	Piezoelectric
Four Corners	Primary and Non Interstate NHS	US Highway 191	Piezoelectric
Gallatin	Primary and Non Interstate NHS	US Highway 191	Piezoelectric
Big Timber[c]	Interstate	Interstate 90	Piezoelectric
Galen	Secondary	Highway 273	Piezoelectric
Broadview	Primary and Non Interstate NHS	State Route 3	Piezoelectric
Miles City East	Primary and Non Interstate NHS	US Highway 12	Piezoelectric
Ulm	Interstate	Interstate 15	Piezoelectric
Ryegate	Primary and Non Interstate NHS	US Highway 12	Piezoelectric
Stanford	Primary and Non Interstate NHS	US Highway 87	Piezoelectric
Fort Benton	Primary and Non Interstate NHS	US Highway 87	Piezoelectric
Havre East	Primary and Non Interstate NHS	US Highway 2	Piezoelectric
Twin Bridges[b]	Primary and Non Interstate NHS	State Route 41	Piezoelectric
Paradise	Primary and Non Interstate NHS	State Route 200	Piezoelectric
Mossmain[a]	Interstate	Interstate 90 W	Piezoelectric Bending plate
		Interstate 90 E	Bending plate
Culbertson[a]	Primary and Non Interstate NHS	State Route 16	Bending plate
Lima[a]	Interstate	Interstate 15	Bending plate
Rocker[b]	Interstate	Interstate 90	Piezoelectric
Armington[a]	Primary and Non Interstate NHS	US Highway 87 W	Piezoelectric
		US Highway 87 E	Piezoelectric
Columbus	Interstate	Interstate 90	Piezoelectric
Bonner	Interstate	Interstate 90	Piezoelectric
Dillon	Interstate	Interstate 90	Piezoelectric
Pryor Creek	Interstate	Interstate 90	Piezoelectric
Wolf Creek	Interstate	Interstate 15	Piezoelectric

[a] PrePass Site (one direction only, unless indicated otherwise)
[b] to be constructed
[c] removed

Details of reports produced by MEARS are shown in Table 3.12. The reports are by site and by month. The percentage of overweight vehicles in reported by class, time period of violation and type of violation. Data is processed continuously for each site.

Table 3.12 MEARS Reports by Site and by Month

25: Overweight Vehicle Report by Class[a]
Number of commercial vehicles
Percent of overweight commercial vehicles
Average amount of legal weight exceedance

30: Overweight Violations by Time Period and Class
Day of week and 4-hour segment of day
Direction of travel

35: Weight Information by Class
Number of commercial vehicles
Percent of overweight commercial vehicles
Average operating weight
Average amount of legal weight exceedance

40: Scatter Graphs by Class[b]
Scatter graph of overweight commercial vehicle events as a function of day of week and time of day

45: Calibration Tracking
Weight frequency plots of vehicles in the traffic stream used for auto-calibration

70: Summary of Records Violating Rules
Total number of records that violate rules validating reasonableness of recorded vehicle characteristics

90: Truck Weight Upload Process Summary Report
Total number of records screened
Total number of bad records

105: Site Activities Roll-up
Total number of vehicles
Total number of commercial vehicles
Percent of overweight commercial vehicles
Average amount of legal weight exceedance
Change in overweight commercial vehicle percent
Change in average legal weight exceedance amount

205: ESAL Report
Excess ESALs attributable to overweight vehicles by duration of reporting period

A two year Pilot Program using focused enforcement approach was employed, as demonstrated in Fig 3.10.

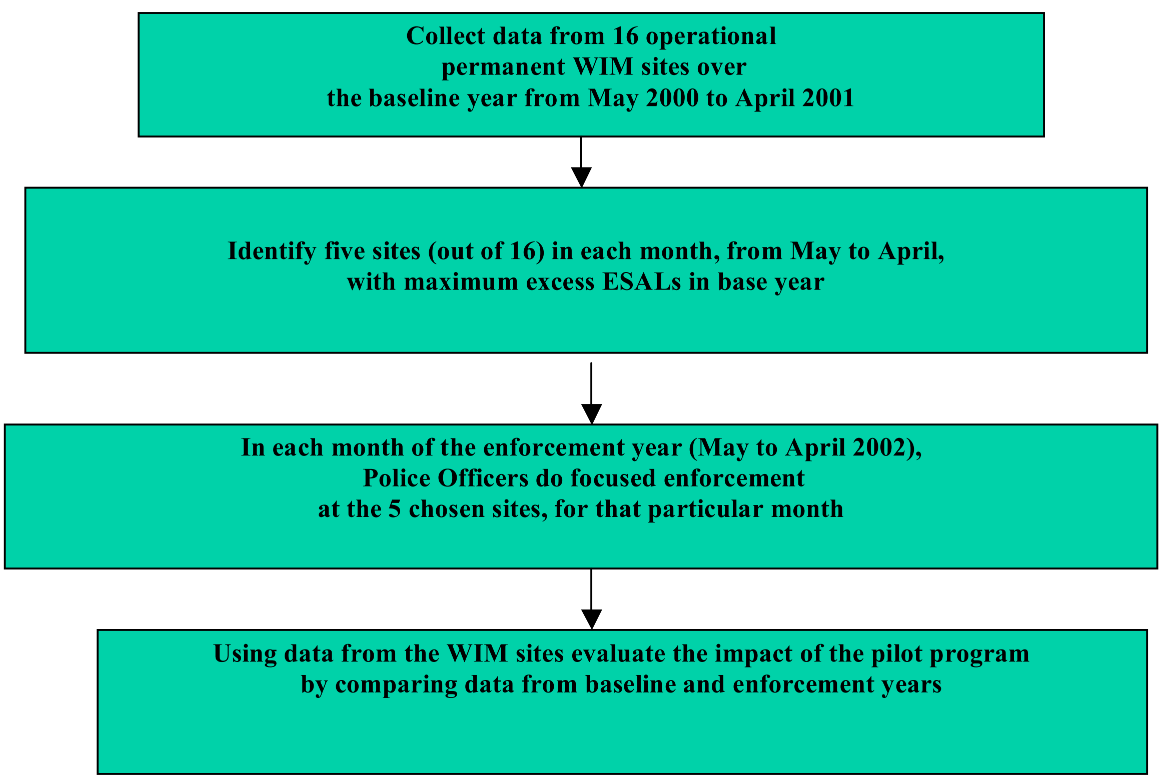

Fig 3.10 The Two-Year Pilot Program – Focused Enforcement

The following points should be noted:

1. There was no real-time use of WIM data at any point.

2. The program only helped identify the locations and time periods with the maximum chance of violations and the types of vehicles most likely to do so, based on baseline year data for each month.
3. Police officers were directed to these spots, where they stopped vehicles and used their static scales to catch violators.

For example, suppose dites A1, B1, C1, D1 and E1 were identified as having encountered the most weight violations in base year for month 1 and A2, B2, C2, D2 and E2 for month 2 and so on, based on data from the baseline year. In the enforcement year, sites A1, B1, C1, D1 and E1 receive focused enforcement during month 1 and sites A2, B2, C2, D2 and E2 during month 2 and so on. The police officers were made available for enforcement at these particular sites during these periods.

3.3.6 Choosing the 5 Worst Affected Sites Each Month: Excess ESAL Factor

An ESAL factor was determined for each vehicle class. The ESAL factor for a vehicle class is the average number of equivalent single axle loads (80psi) associated with each vehicle of the class. Typical calculations were performed as follows:

Nx : number of vehicles of class X,
ESALx : the ESAL factor for class X,
Number of ESAL for vehicles of class X = Nx*ESALx

The selection of sites was done based on the total excess ESAL. Where the total excess ESAL is defined as follows:

Based on data available from MEARS for each site we calculate:

Excess-ESAL-factor-class-I = Difference in ESAL factor for average overweight vehicle of class-I and the ESAL factor for vehicle of class-I operating at maximum legal weight

Total Excess ESAL =
$\sum$ (No. of overweight vehicles in class i) * (Excess-ESAL-factor-class-I)

Every month the top 5 sites with the maximum value for this total excess ESAL were chosen for focused enforcement during the enforcement year. Fig 3.11 shows the typical excess ESAL for each STARS site for the month of October in the base year. Surprisingly Decker was chosen over Ryegate and Miles City East, although it showed lower excess ESAL value (no explanation was provided for this).

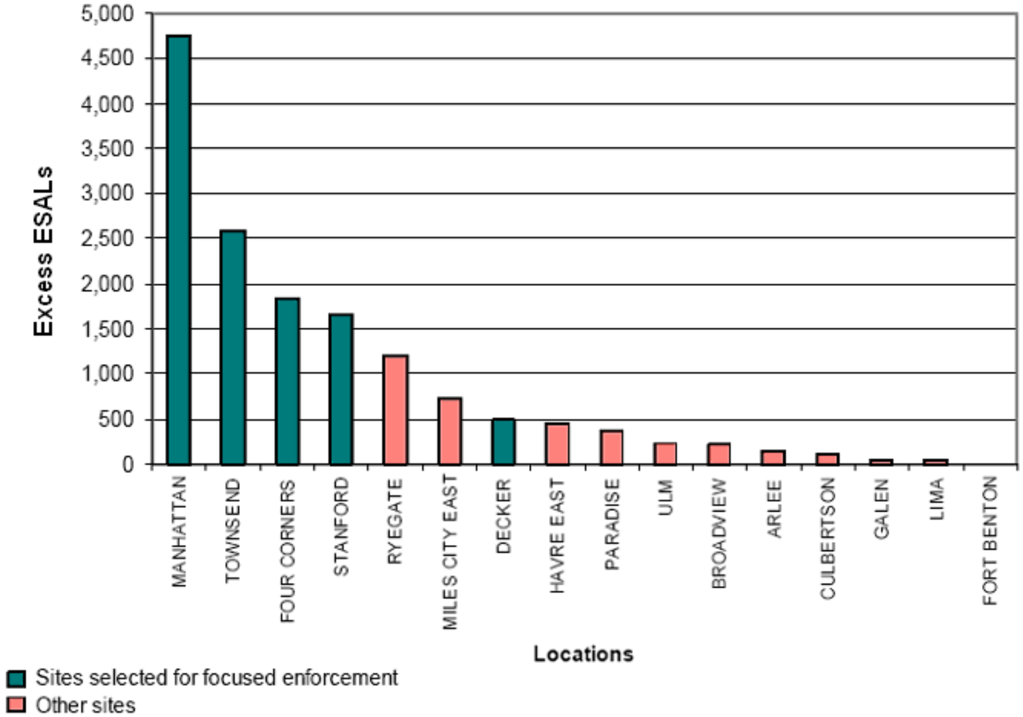

Fig 3.11 Typical Pavement Damage for Every STARS Site for October 2000 (Base Year)

Table 3.13 Sites Selected for Focused Enforcement Based on Baseline Year Data

	2001[c]								2002[c]			
Site	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar[b]**	**Apr[b]**
Townsend	X	X	X	X	X	X	X	X			X	X
Decker					X	X				X		
Bad Route[a]	X		X	X								
Manhattan						X			X			
Arlee			X						X			
Four Corners/Gallatin	X	X X	X	X	X	X	X	X X	X	X	X	X
Big Timber[a]	X	X										
Galen												
Broadview												
Miles City East				X								
Ulm							X	X	X	X		
Ryegate					X		X	X	X	X	X	X
Stanford	X	X	X	X	X	X	X			X	X	X
Fort Benton												
Havre East												
Paradise												
Culbertson												
Lima												

[a] Removed from analysis due to WIM equipment/pavement problems
[b] Focused enforcement occurred at only four sites due to patrol officer staffing constraints
[c] X indicates site was selected for enforcement during the indicated month of the enforcement year
XX indicates site was selected for intensive enforcement (twice the regular schedule) during the indicated month of the enforcement year

The sites selected from baseline year data are shown in Table 3.13.
Due to the limited number of available officers, enforcement was typically done for 3 days every week and 8 hours each day, located at each of the 5 chosen sites for the particular month.

Table 3.14 shows the typical officer's schedule generated from the WIM data. Typical information provided to the enforcement officers was:

1. Site and day of week
2. Critical time of day – when violations were most expected
3. Direction of travel
4. Vehicle configuration

This kind of information is often invaluable to the enforcement officers.

Table 3.14 Monthly Focused Enforcement Schedule Generated by WIM System Data

Site	Day of Week	Critical Time of Day	Direction of Travel and Vehicle Configuration(s)
Townsend	Monday	8:00 am to 4:00 pm	9, 10 East or West; 13 West
	Tuesday	8:00 am to 4:00 pm	9 East or West; 10 East, 13 West
	Wednesday	8:00 am to 4:00 pm	9, 10 East or West; 13 West
Decker	Monday	8:00 am to 8:00 pm	13, 10 North; 9 North or South; 6 North
	Wednesday	8:00 am to 8:00 pm	13, 10 North; 9 North or South
	Friday	8:00 am to 8:00 pm	13, 10 North; 9 North or South
Gallatin	Monday	noon to midnight 4:00 am to noon	9, 6 North or 9, 13 South
	Tuesday	noon to midnight	9, 6 North
	Friday	noon to midnight	9, 6 North
Manhattan	Monday	8:00 am to 8:00 pm	10, 9 West; 6 East
	Wednesday	8:00 am to 8:00 pm	10, 9 West; 6 East
	Thursday	8:00 am to 8:00 pm	10, 9 West; 6 East
Stanford	Monday	Noon to midnight	9, 10 East or West
	Tuesday	Noon to midnight	9, 10 West
	Friday	Noon to midnight	9, 10 West

During enforcement the officers measured axle weights using portable scales. Each available officer had a choice of time for enforcement and type of vehicle.

3.3.7 Affected Mileage

As shown in Fig 3.12, the length of the road on which the WIM site was located, between two intersections, was taken as the affected mileage under influence of this WIM station.

3.3.7.1 By-pass

It can be concluded that there was no significant switching of routes by the trucks to avoid the WIM stations based on the two following arguments:

1. There are very few alternate routes available to the truck drivers in Montana.

2. The 62 portable (intermittently operated) WIM stations were used to keep a check on such activities on unmonitored routes. No significant by-passing activity was reported.

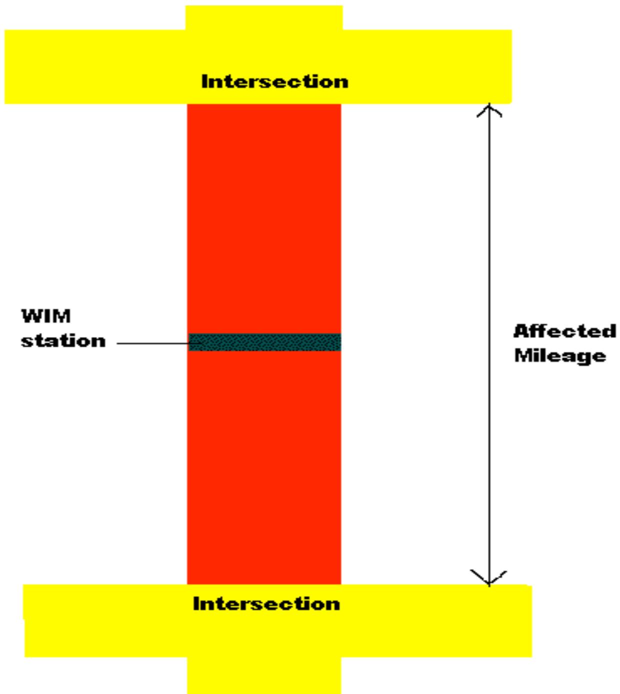

Fig 3.12 Estimating Affected Mileage

3.3.8 Evaluation Results:

A 22% decrease in the percentage of overweight commercial vehicles in the traffic stream across the 16 STARS sites was observed. There was a decrease in overweight vehicle percentage in the traffic stream from 8.8% in baseline year to 6.9% in enforcement year. Results varied based on the different number of months of focused enforcement at each site

3.3.8.1 Changes in overweight commercial vehicle population

A typical site with 7 months of focused enforcement is shown in Fig 3.13. There is significant decrease in the overweight vehicle population, especially during the enforced months.

On the other hand Fig 3.14 shows a site for which we had 2 months of focused enforcement. No significant improvement appears in this case.

The sites with no enforcement display interesting results. Fig 3.15 and 3.16 represent two typical scenarios. In half the cases there was reduction, as in Fig 3.16, while in the other half there was an increase, as in Fig 3.15. No suitable explanation can be obtained for these sites but overall the results tend to cancel out.

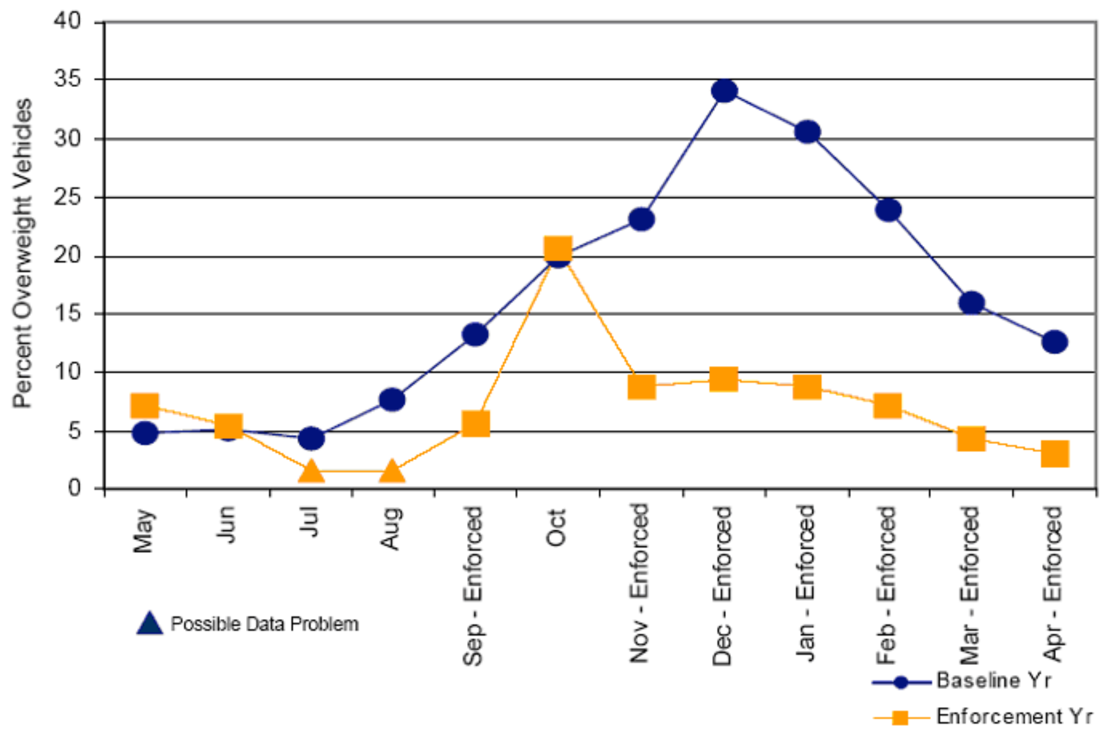

Fig 3.13 Percent Overweight Commercial Vehicles by Month at the **Ryegate** *STARS* Site, Baseline and Focused Enforcement Year

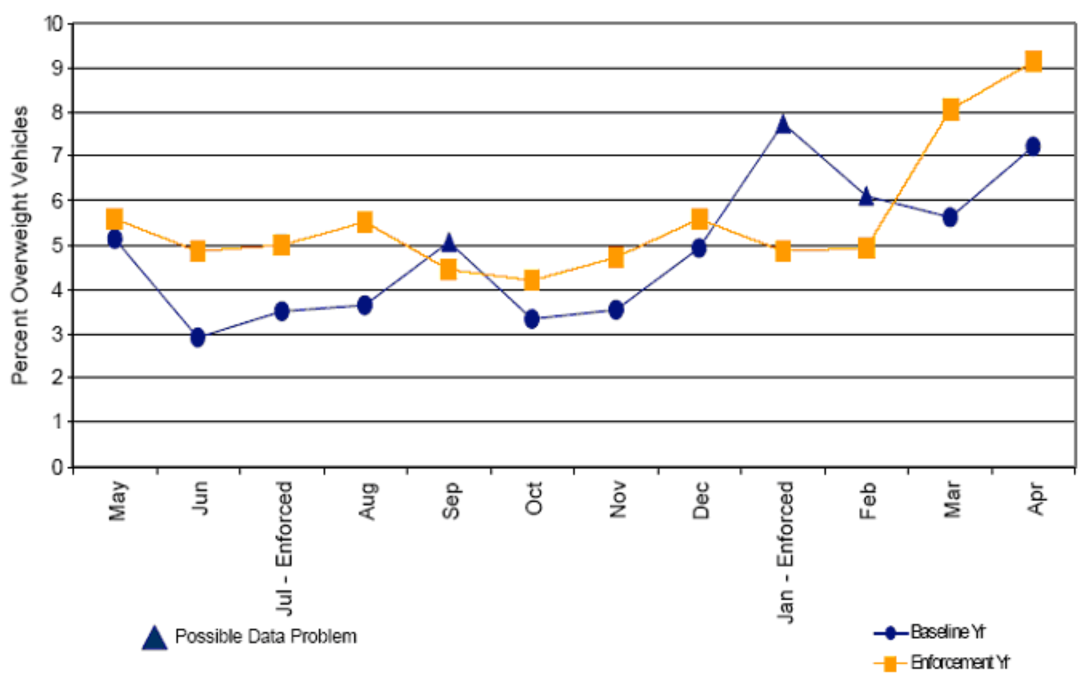

Fig 3.14 Percent Overweight Commercial Vehicles by Month at the **Arlee** *STARS* Site, Baseline and Focused Enforcement Year

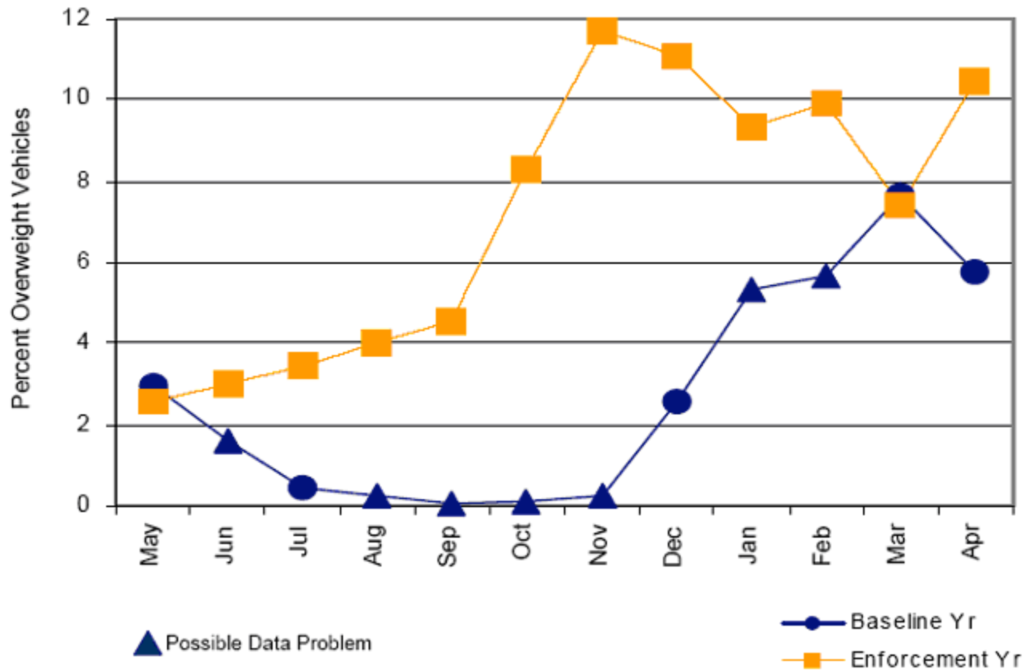

Fig 3.15 Percent Overweight Commercial Vehicles by Month at the **Fort Benton** *STARS* Site, Baseline and Focused Enforcement Year

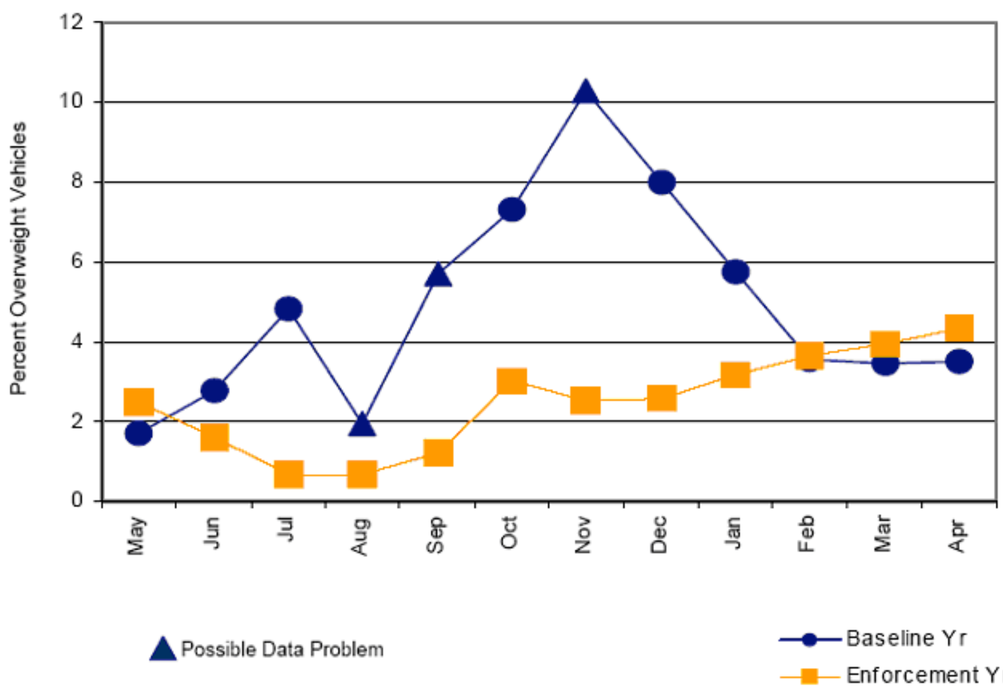

Fig 3.16 Percent Overweight Commercial Vehicles by Month at the **Havre East** *STARS* Site, Baseline and Focused Enforcement Year

Formal Statistical Analyses Results:
The total number of observation points is 192 (12 months for each of the 16 sites). However, 144 data points were available for analysis (due to equipment failure, etc.). Out of these, 40 were enforced months and 104 were non-enforced months. Results obtained were as follows:

- There was a statistically significant reduction for 32 out of 40 enforced months, which is an 80% reduction.
- There was a statistically significant reduction for 33 out of 104 non-enforced months, which is a mere 32% reduction.

3.3.8.2 Commercial Vehicle Weight Distribution
Again results were different for different sites depending on the number of enforced months. The results below are for Class 9 vehicles, the group responsible for maximum overweight violations in baseline year. Fig 3.17 shows the gross vehicle weight distribution over all sites with more than 6 months of focused enforcement. There is a clear shift in the weight distribution curve towards the left of the curve for the enforcement year over the curve for the baseline year. The vertical line represents the legal limit of 80,000lb for this vehicle class.

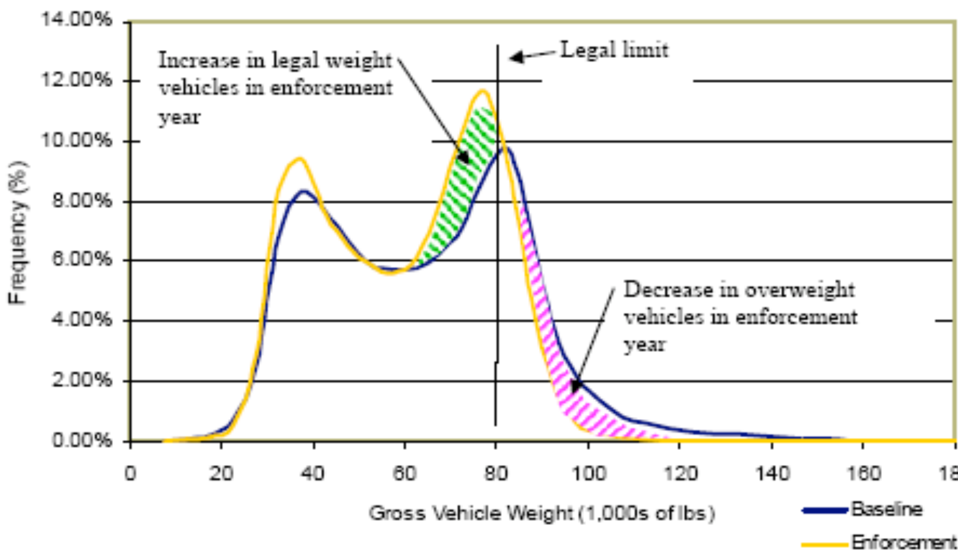

Fig 3.17 Vehicle Weight Distribution for Class 9 over All Sites with More than 6 Months of Focused Enforcement

Similar curves for sites with 1-6 months of enforcement and no enforcement are shown in Fig 3.18 and 3.19. No noticeable trend can be inferred from the graphs.

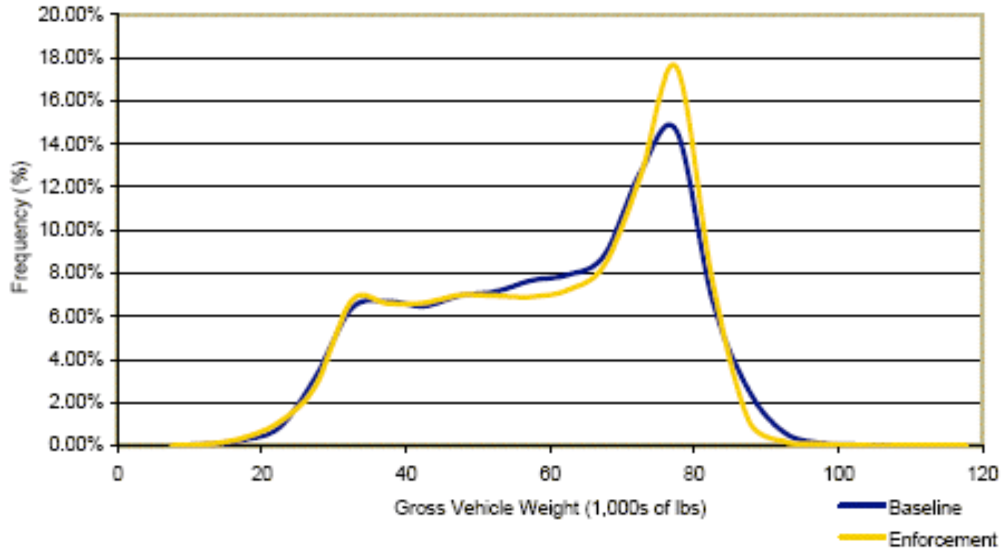

Fig 3.18 Vehicle Weight Distribution for Class 9 over All Sites with 1 to 6 Months of Focused Enforcement

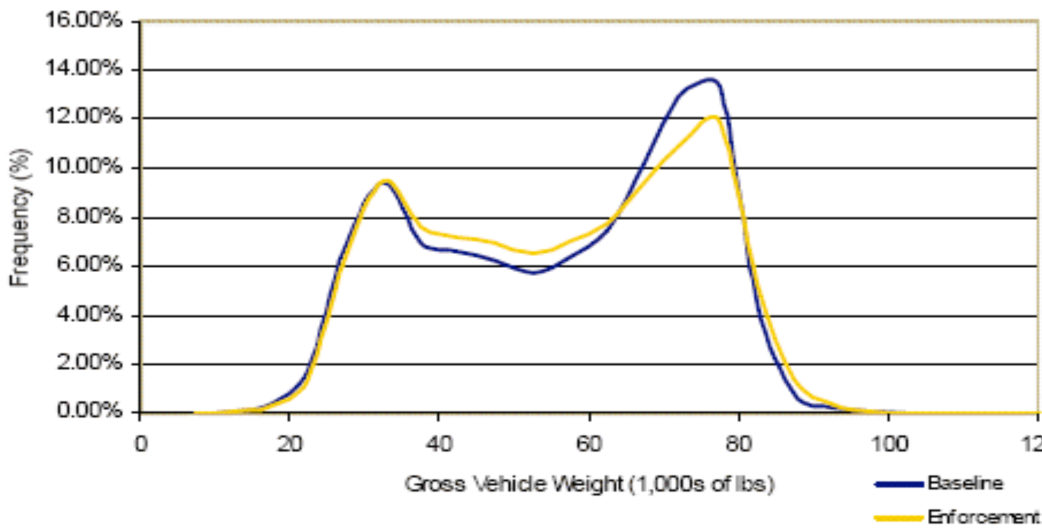

Fig 3.19 Vehicle Weight Distribution for Class 9 over All Sites with No Focused Enforcement

3.3.8.3 Average Commercial Vehicle Weight Exceedance

Overall the average weight exceeded decreased by 16% over all sites. The average weight exceeded was 6100 pounds during the baseline year and 5100 pounds in the enforcement year. The trend of this decrease with respect to the sites and months is similar to that observed for the decrease in the percentage of overweight commercial vehicles in traffic stream

3.3.8.4 Predicted Pavement Impact Prediction

The pavement impact comparison was performed using ESAL-miles given by:
ESAL-miles = ESAL * Affected Mileage

The decrease in pavement impact attributable to overweight vehicles during the enforcement year was predicted.

To evaluate the role of the STARS program in this decrease, the traffic volume should remain constant over the baseline and enforcement years so that the percentage of overweight vehicles is the only factor. For this the traffic volume in baseline year was adjusted by a factor to account for the difference in the amount of freight moved in the highway system during baseline and enforcement years. The factor was estimated using the following:

1. The volume of traffic in the 2 years
2. The relative proportion of overweight vehicles in traffic stream in the 2 years
3. The average amount of weight exceeded in the 2 years

Relative to the baseline year, there was a decrease of **6-million ESAL-miles** during the year of STARS enforcement. Again, sites were analyzed based on the number of months of focused enforcement. Fig 3.20 shows the predicted pavement impact change between the baseline and enforcement year for a site with more than 6 months of focused enforcement. There was a substantial improvement over the baseline year.

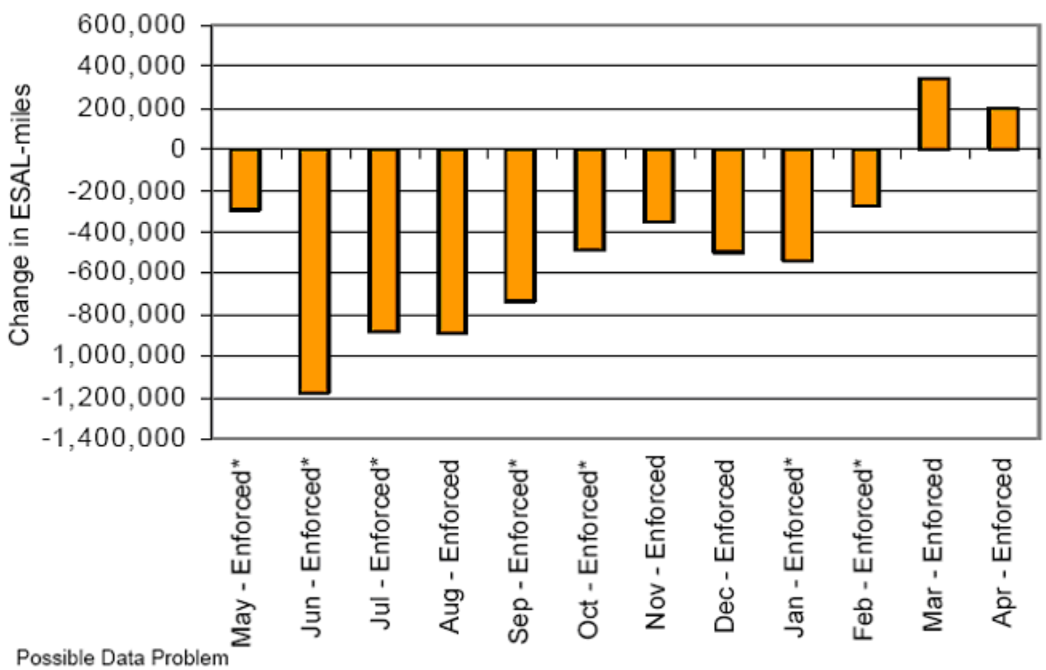

Fig 3.20 Change in Predicted Pavement Impact for a Site with More than 6 <onths of Focused Enforcement

On the contrary, no discernible trend is observed for the site with 2 months of focused enforcement and completely opposite results are obtained for a typical site with no focused enforcement. These are shown in Fig 3.21 and 3.22. The graph shown in Fig 3.22 raises the question whether overloads are just being transferred from a focused enforcement site to a non-focused enforcement site. To reach a final conclusion we need to analyze the statewide data shown in Fig 3.23 and 3.24.

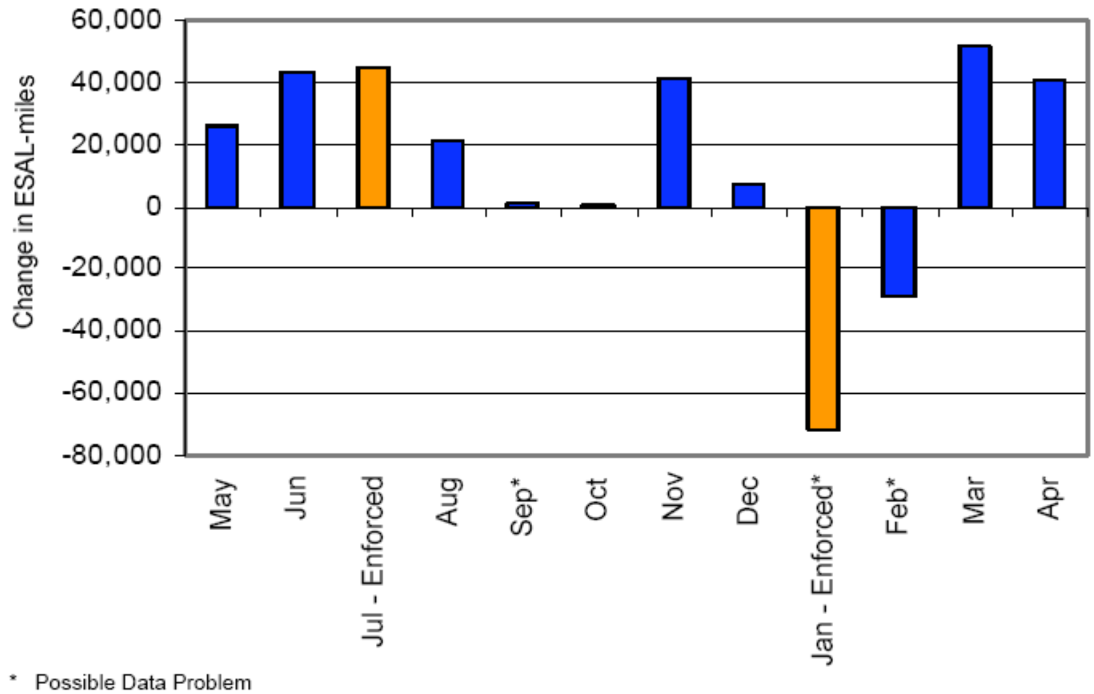

Fig 3.21 Change in Predicted Pavement Impact for a Site with 2 Months of Focused Enforcement

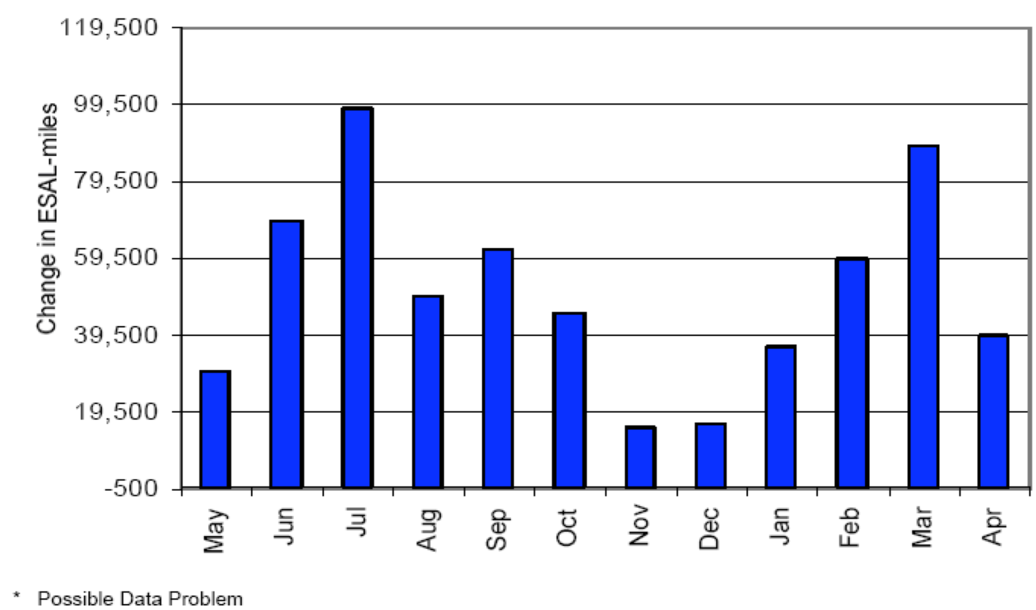

Fig 3.22 Change in Predicted Pavement Impact for a Site with No Focused Enforcement

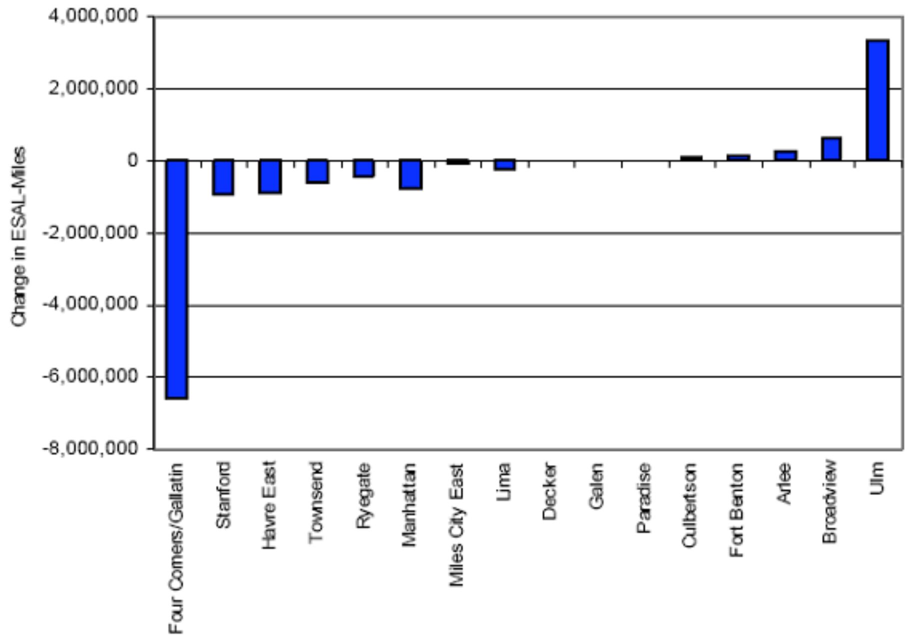

Fig 3.23 Total Change in Pavement Damage by Site, Baseline to Focused Enforcement Year

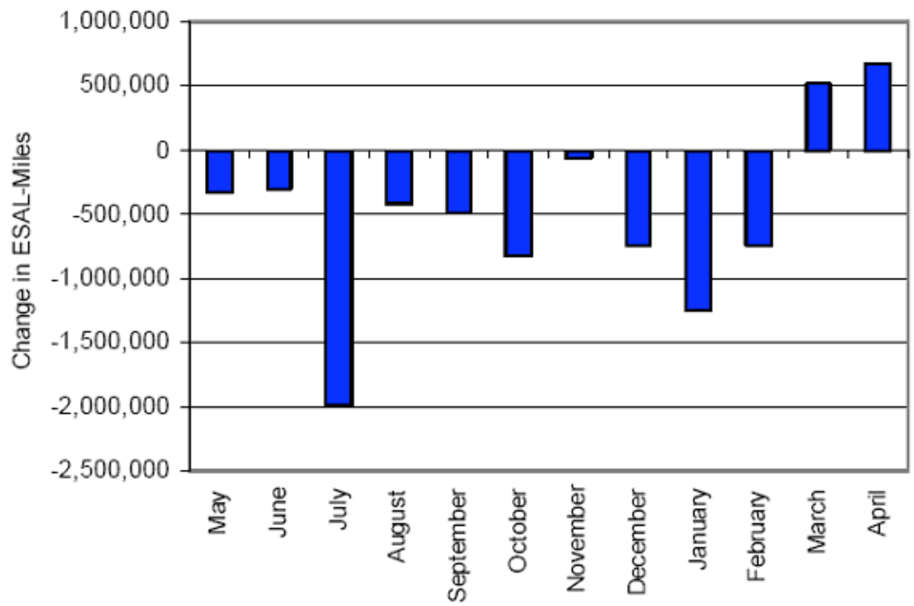

Fig 3.24 Statewide Change in Pavement Damage by Month, Baseline to Focused Enforcement Year

From the above graphs it is clear that there is a reduction in the estimated ESAL miles when the data from the entire state is considered. As reported previously, relative to the baseline year, there was a decrease of **6-million ESAL-miles** during the year of STAR enforcement.

3.3.8.5 Predicted Pavement Cost Savings

Each pavement is designed to withstand a certain number of ESAL.
A cost was estimated for each ESAL-mile based on a cost allocation study for the Montana highway system by Stephens and Menuez.

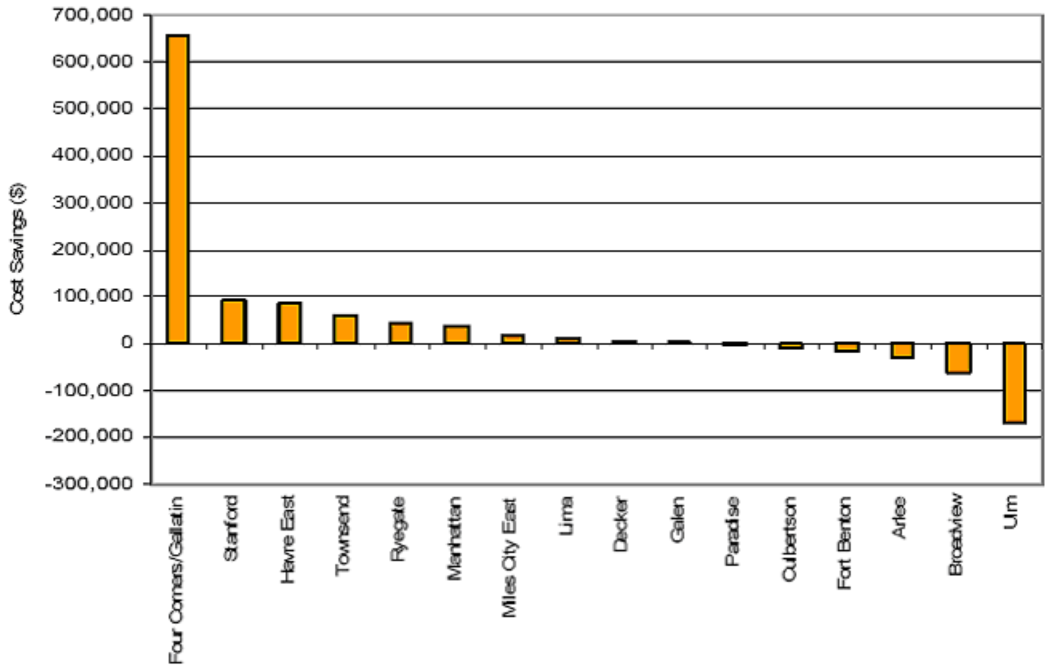

Fig 3.25 Total Cost Savings by Site, Baseline to Focused Enforcement Year

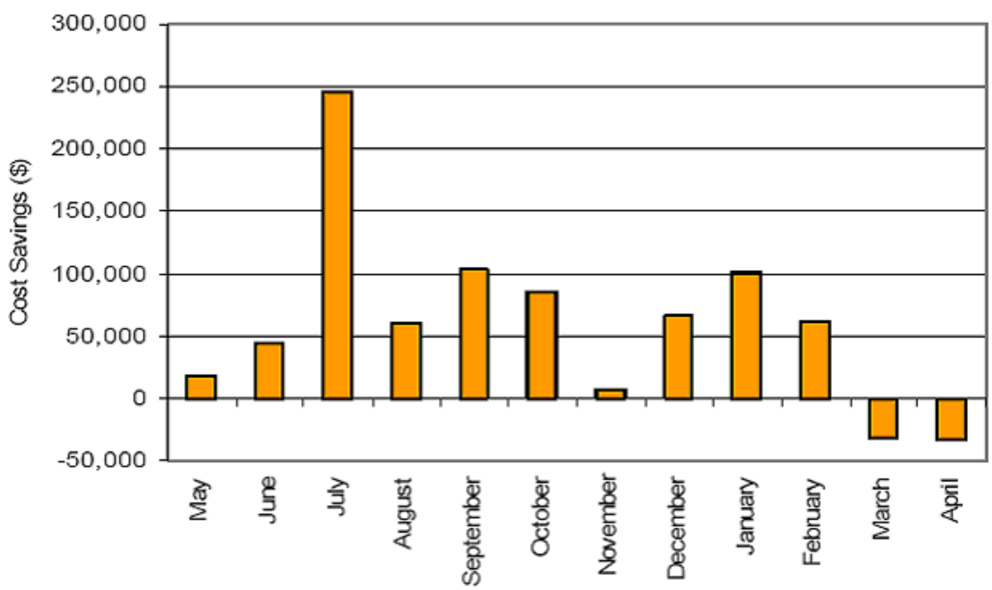

Fig 3.26 Statewide Cost Savings by Month, Baseline to Focused Enforcement Year

Its value depended on the type of highway system (i.e., interstate, primary and secondary). These costs were adjusted for inflation. The cost was estimated to be from $0.05/ESAL-mile to $0.31/ESAL-mile for year 2000-2001, depending on the type of system. At each site the ESAL-miles was multiplied by this cost factor and results were summed up.
Results are shown in Fig 3.25 & 3.26. The predicted cost associated with the statewide reduction in excess ESALs attributed to STARS-directed enforcement was estimated to be **$700,000.**

3.3.8.6 Number of Citations

The number of citations is not an adequate performance measure, especially when direct measures of performance are available. Statistical analysis revealed that there was no statistically significant increase in the number of citations issued during the enforcement year over the baseline year

3.3.9 Summary:

The STARS pilot program has achieved the following:

1. A 22% decrease of overweight vehicles in traffic stream
2. A 16% decrease in the average amount of exceeded weight
3. A $0.7 million decrease in predicted pavement reconstruction costs

Based on this data, the STARS program can be categorized as a success. This program, however, made an indirect (non-real time) use of WIM data in the enforcements. A direct (real time) use of WIM data could lead to more efficient enforcements. For this the accuracy of WIM systems needs to be evaluated, as it remains an issue of debate whether citations can be issued solely based on the data from WIM equipment.

4: CALIFORNIA: WIM AVAILABILITY AND DATA ANALYSIS

This section summarizes the report **"**Truck Traffic Analysis using Weigh-In-Motion (WIM) Data in California" by Harvey et al. (2002).
Section 4.1 describes the location of the existing WIM stations in California and the kind of data available from them. Section 4.2 discusses the analysis that was carried out on this data. Sections 4.2.4.1 to 4.2.4.13 briefly outline the results of each of these analyses that were conducted on the WIM data. A detailed account can be obtained from the original report.

4.1 WIM Data Availability in California

4.1.1 Data Availability

Over 100 WIM stations are installed on the California highway system. The distribution is shown in Fig 4.1.

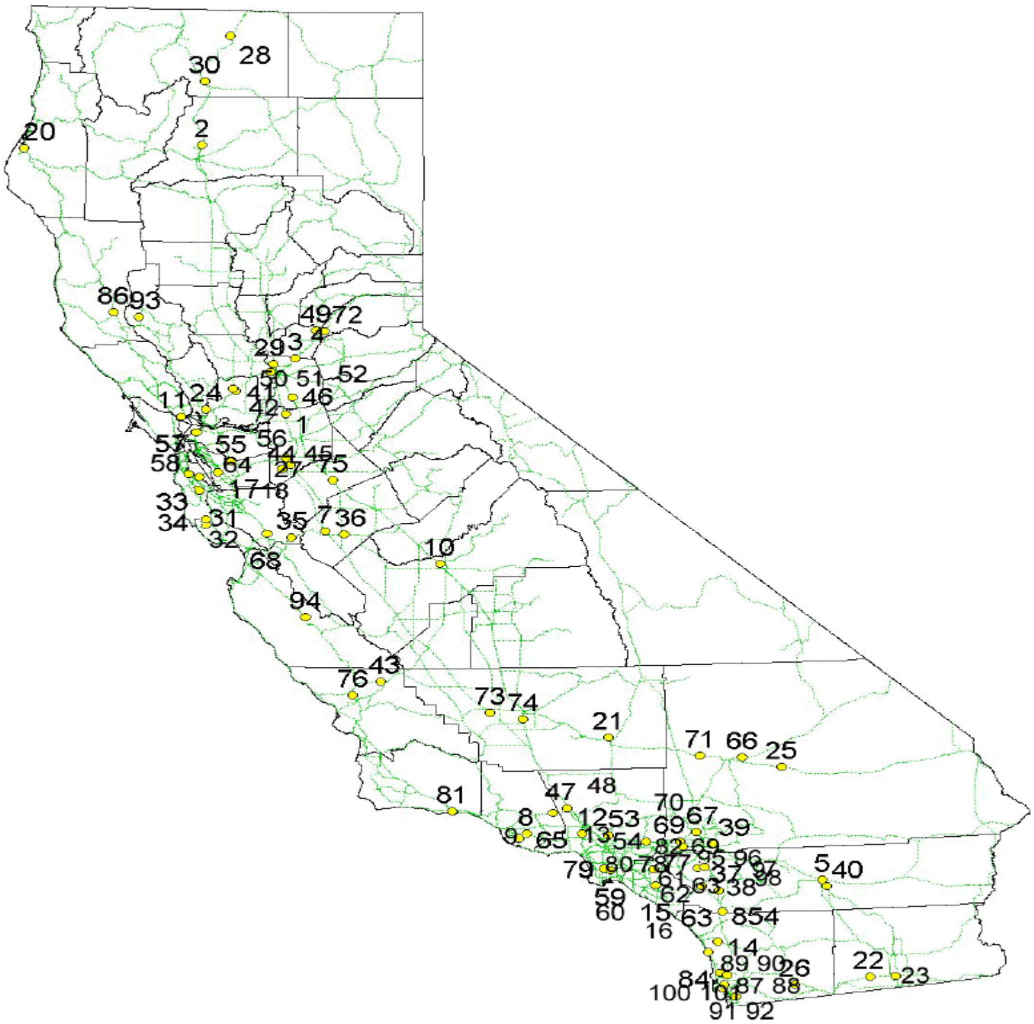

Fig 4.1 Distribution of WIM Stations in the California State Highway Network in March 2001

The WIM station systems used by Caltrans were provided by two different vendors:

1. PAT Traffic Control Corporation
2. International Road Dynamics Inc.

Table 4.1 Basic Information on Each WIM Stations in California in March 2001

Station No.	Location Information					Data System (Vendor)	Lane Configuration	
	Name	District	County	Route	Postmile		No. of Lanes	Direction[1]
1	Lodi	10	San Joaquin	5	43.7	DAW 200	4	1234(N2N1S1S2)
2	Redding	2	Shasta	5	R24.9	DAW 200 (7/99)	4	1234(S2S1N1N2)
						IRD (7/99-Pres)	4	1234(N2N1S1S2)
3	Antelope	3	Sacramento	80	15	DAW 200 (8/95)	4	1234(W4W3W2W1)
	Antelope (EB)-After 95					IRD (8/95-Pres)	4	1234(E4E3E2E1)
4	Antelope (WB)-After 98	3	Sacramento	80	17.2	IRD	4	1234(W4W3W2W1)
5	Indio	8	Riverside	10	R59.4	DAW 200 (4/00)	4	1234(E2E1W1W2)
						IRD (4/00-Pres)	4	1234(W2W1E1E2)
6	Newhall-Before 98	7	Los Angeles	5	44.6	DAW 200	2	14(N1N2)
	Palmdale	7	Los Angeles	14	R57.8	*SITE INSTALLATION PENDING		
7	Santa Nella	10	Merced	5	20.2	DAW 200	4	1234(S2S1N1N2)
8	Ventura(SB)	7	Los Angeles	101	37.8	DAW 200 (8/99)	6	SSSSS
	Conejo (SB)	7	Ventura	101	12	DAW 190 (8/99-Pres)	3	123(S3S2S1)
9	Ventura(NB)	7	Los Angeles	101	37.8	DAW 200 (8/99)	6	NNNNN
	Conejo (NB)		Ventura		7.7	DAW 190 (8/99-Pres)	3	123(N3N2N1)
10	Fresno	6	Fresno	99	25	DAW 200	6	123456(S3S2S1N1N2N3)
11	Sonoma	4	Sonoma	37	2.7	DAW 200	4	1234(W2W1E1E2)
12	Van Nuys (SB)	7	Los Angeles	405	42.9	DAW 200 (6/94)	5	12345(S5S4S2S1S3)
						DAW 190 (6/94-Pres)	5	12345(S5S4S3S2S1)
13	Van Nuys (NB)	7	Los Angeles	405	42.9	DAW 200 (6/94)	5	12345(N5N4N2N1N3)
						DAW 190 (6/94-Pres)	5	12345(N5N4N3N2N1)
14	San Marcos	11	San Diego	78	10.7	DAW 200	6	123456(E3E2E1W1W2W3)
15	Irvine (SB)	12	Orange	5	25.8	DAW 200 (1/98)	6	123456(S6S5S3S2S4S1)
						DAW 190 (1/98-Pres)	6	123456(S6S5S4S3S2S1)
16	Irvine (NB)	12	Orange	5	25.8	DAW 200 (1/98)	6	123456(N6N5N3N2N4N1)
						DAW 190 (1/98-Pres)	6	123456(N6N5N4N3N2N1)
17	Hayward (SB)	4	Alameda	880	14.7	DAW 200	6	123456(S6S5S3S2S4S1)
18	Hayward (NB)	4	Alameda	880	14.7	DAW 200	6	123456(N6N5N3N2N4N1)
19	Martinez	4	Contra Costa	4	11.2	*SITE INSTALLATION PENDING		
20	Loleta	1	Humboldt	101	65.6	DAW 200	4	1234(N2N1S1S2)
21	Mojave	6	Kern	58	108.1	DAW 200	4	1234(E2E1W1W2)
22	Jeffrey	11	Imperial	8	25.8	DAW 200	4	1234(E2E1W1W2)
23	El Centro	11	Imperial	8	40	DAW 200	4	1234(E2E1W1W2)
24	Napa	4	Napa	12	2.3	DAW 200	2	14(W1E1)
25	Newberry	8	San Bernardino	40	28.9	DAW 200	4	1234(E2E1W1W2)
26	Cameron	11	San Diego	8	51.5	DAW 200	4	1234(E2E1W1W2)
27	Tracy	10	San Joaquin	5	7.4	DAW 200	4	1234(S2S1N1N2)
28	Macdoel	2	Siskiyou	97	34.5	IRD	2	12(S1N1)
29	Arco (SB)	3	Sacramento	5	28.9	IRD	3	123(S1S2S3)
30	Mt Shasta	2	Siskiyou	5	11.4	DAW 200	4	1234(S2S1N1N2)
31	Woodside (SB)	4	San Mateo	280	5.6	DAW 200	6	123456(S6S53S2S4S1)
32	Woodside (NB)	4	San Mateo	280	5.6	DAW 200	6	123456(N6N5N3N2N4N1)
33	Burlingame (SB)	4	San Mateo	101	17.5	DAW 200	6	123456(S6S53S2S4S1)
34	Burlingame (NB)	4	San Mateo	101	17.5	DAW 200	6	123456(N6N5N3N2N4N1)
35	Pacheco	4	Santa Clara	152	26.9	DAW 200	4	1234(W2W1E1E2)
36	Los Banos	10	Merced	152	23	DAW 200	4	1234(W2W1E1E2)
37	Elsinore (SB)	8	Riverside	15	21.6	DAW 200(11/99)	6	123456(S6S53S2S4S1)
						DAW 190(11/99-Pres)	6	123456(S6S5S4S3S2S1)
38	Elsinore (NB)	8	Riverside	15	21.6	DAW 200(11/99)	6	123456(N6N5N3N2N4N1)
						DAW 190(11/99-Pres)	6	123456(N6N5N4N3N2N1)
39	Redlands	8	San Bernardino	30	31.7	DAW 200	4	1234(E2E1W1W2)
40	Coachella	8	Riverside	86	R16	DAW 200	4	1234(N2N1S1S2)
41	Vacaville (EB)	4	Solano	80	30.6	IRD	4	1234(E4E3E2E1)
42	Vacaville (WB)	4	Solano	80	30.6	IRD	4	1234(W4W3W2W1)
43	Cholame	5	San Luis Obispo	46	44.7	IRD	2	12(E1W1)
44	Banta	10	San Joaquin	205	R9.5	DAW 200 (8/00)	4	1234(W2W1E1E2)
						DAW 190 (8/00-Pres)	4	1234(W2W1E1E2)
45	Carbona	10	San Joaquin	580	6.4	DAW 200	4	1234(E2E1W1W2)
46	Galt	3	Sacramento	99	6.9	IRD	4	1234(S2S1N1N2)
47	Castaic (SB)	7	Los Angeles	5	R56.1	DAW 200	6	123456(S6S53S2S4S1)
48	Castaic (NB)	7	Los Angeles	5	R56.1	DAW 200	6	123456(N6N5N3N2N4N1)
49	Auburn	3	Placer	49	9	DAW 200	4	1234(N2N1S1S2)
50	Elmira	4	Solano	505	2.2	IRD	4	1234(N2N1S1S2)
51	West Sac (EB)	3	Yolo	50	0.6	IRD	4	1234(E4E3E2E1)

Station No.	Location Information					Data System (Vendor)	Lane Configuration	
	Name	District	County	Route	Postmile		No. of Lanes	Direction[1]
52	West Sac (WB)	3	Yolo	50	0.6	IRD	4	1234(W4W3W2W1)
53	Montrose (EB)	7	Los Angeles	2	21.9	*SITE ABANDONED		
54	Montrose (WB)	7	Los Angeles	2	21.9	*SITE ABANDONED		
55	Dublin (SB)	4	Contra Costa	680	R0.1	DAW 100	4	1234(S4S3S2S1)
56	Dublin (NB)	4	Contra Costa	680	R0.1	DAW 100	4	1234(N4N3N2N1)
57	Pinole (EB)	4	Contra Costa	80	7.5	DAW 200	6	123456(E6E5E3E2E4E1)
58	Pinole (WB)	4	Contra Costa	80	7.5	DAW 200	6	123456(W6W5W3W2W4W1)
59	LA - 710 (SB)	7	Los Angeles	710	11.5	IRD	4	1234(S4S3S2S1)
60	LA - 710 (NB)	7	Los Angeles	710	11.5	IRD	4	1234(N4N3N2N1)
61	Peralta (EB)	12	Orange	91	11.9	IRD	4	1234(E4E3E2E1)
62	Peralta (WB)	12	Orange	91	11.9	IRD	4	1234(W4W3W2W1)
63	Murrieta	8	Riverside	215	R15	DAW 100	4	1234(N2N1S1S2)
64	Foster City	4	San Mateo	92	14.1	IRD	6	123456(W3W2W1E1E2E3)
65	Piru	7	Ventura	126	30.8	DAW 100	4	1234(W2W1E1E2)
66	Calico	8	San Bernardino	15	R81.4	IRD	4	1234(N2N1S1S2)
67	Devore	8	San Bernardino	215	14.8	DAW 100	4	1234(N2N1S1S2)
68	Gilroy	4	Santa Clara	101	R9.8	IRD	6	123456(S3S2S1N1N2N3)
69	Fontana (SB)	8	San Bernardino	15	6.1	DAW 100	4	1234(S4S3S2S1)
70	Fontana (NB)	8	San Bernardino	15	6.1	DAW 100	4	1234(N4N3N2N1)
71	Hinkley	8	San Bernardino	58	19.7	DAW 100	4	1234(W2W1E1E2)
72	Bowman	3	Placer	80	23.4	IRD	6	123456(W3W2W1E1E2E3)
73	Stockdale	6	Kern	5	48.7	IRD	4	1234(N2N1S1S2)
74	Bakersfield	6	Kern	99	20.2	IRD	6	123456(N3N2N1S1S2S3)
75	Keyes	10	Stanislaus	99	R8.4	IRD	6	123456(N3N2N1S1S2S3)
76	Templeton	5	San Luis Obispo	101	49.5	IRD	4	1234(S2S1N1N2)
77	Colton (EB)	8	San Bernardino	10	12.4	IRD	4	1234(E4E3E2E1)
78	Colton (WB)	8	San Bernardino	10	12.4	IRD	4	1234(W4W3W2W1)
79	Artesia (EB)	7	Los Angeles	91	7.5	IRD	5	12345(E4E3E2E1,E(HOV))
80	Artesia (WB)	7	Los Angeles	91	7.5	IRD	5	12345(W4W3W2W1,W(HOV))
81	Positas	5	San Benito	101	16.2	IRD	6	123456(N3N2N1S1S2S3)
82	Glendora (EB)	7	Los Angeles	210	42.6	IRD	5	12345(E4E3E2E1,E(HOV))
83	Glendora (WB)	7	Los Angeles	210	42.6	IRD	5	12345(W4W3W2W1,W(HOV))
84	Leucadia (SB)	11	San Diego	5	42.2	IRD	4	1234(S4S3S2S1)
85	Leucadia (NB)	11	San Diego	5	42.2	IRD	4	1234(N4N3N2N1)
86	Ukiah	1	Mendocino	101	21.9	DAW 190	4	1234(S2S1N1N2)
87	Balboa (SB)	11	San Diego	15	10	IRD	4	1234(S4S3S2S1)
88	Balboa (NB)	11	San Diego	15	10	IRD	4	1234(N4N3N2N1)
89	Dekema (SB)	11	San Diego	805	24.5	IRD	4	1234(S4S3S2S1)
90	Dekema (NB)	11	San Diego	805	24.5	IRD	4	1234(N4N3N2N1)
91	Poggi (SB)	11	San Diego	805	5.6	IRD	4	1234(S4S3S2S1)
92	Poggi (NB)	11	San Diego	805	5.6	IRD	4	1234(N4N3N2N1)
93	Lakeport	1	Lake	29	44.4	IRD	4	1234(N2N1S1S2)
94	Greenfield	5	Monterey	101	47.9	IRD	4	1234(S2S1N1N2)
95	Ontario (EB)	8	San Bernardino	60	R7.9	IRD	3	123(E3E2E1)
96	Ontario (WB)	8	San Bernardino	60	R7.9	IRD	3	123(W3W2W1)
97	Chino	8	San Bernardino	83	5.7	IRD	4	1234(N2N1S1S2)
98	Prado	8	San Bernardino	71	R5.8	IRD	4	1256(S3S2N2N3)
99	Tulloch	10	Tuolumne	120	6.4	IRD	4	1234(E2E1W1W2)
100	Miramar (SB)	11	San Diego	163	10.4	DAW 190	5	12345(S5S4S3S2S1)
101	Miramar (NB)	11	San Diego	163	10.4	DAW 190	4	1235(N4N3N2N1)

[1] The lane numbers in the parentheses are Caltrans lane number designation. (e.g.,W2 represents westbound second lane from the centerline)

The basic information for each of the WIM stations as of March 2001 is provided in Table 4.1. For each station the district, county, route, post-mile, vendor (PAT/IRD), the number of lanes and lane numberings are provided.
The lane numbering according to the WIM hardware is shown in brackets. Because the WIM storage hardware was installed in random order, they have been converted to the California numbering system with 1 representing the innermost lane.

Table 4.2 Fields in the ASCI I Data Files

Field	PAT Data Type by Field	IRD Data Type by Field
1	Lane	Lane
2	Month	Month
3	Day	Day
4	Year	Year
5	Hour	Hour
6	Minute	Minute
7	Second	Second
8	Vehicle Number	Vehicle Number
9	Type	Type
10	Gross weight (kips)	Gross weight (kips)
11	Overall length (feet)	Overall length (feet)
12	Speed (mph)	Speed (mph)
13	Violation code	Violation code
14	Axle 1 Right Side weight (kips)	Axle 1 Right Side weight (kips)
15	Axle 1 Left Side weight (kips)	Axle 1 Left Side weight (kips)
16	Axle 2 Right Side weight (kips)	Axle 2 Right Side weight (kips)
17	Axle 2 Left Side weight (kips)	Axle 2 Left Side weight (kips)
18	Spacing between Axles 1 & 2 (feet)	Spacing between Axles 1 & 2 (feet)
19	Axle 3 Right Side weight (kips)	Axle 3 Right Side weight (kips)
20	Axle 3 Left Side weight (kips)	Axle 3 Left Side weight (kips)
21	Spacing between Axles 2 & 3 (feet)	Spacing between Axles 2 & 3 (feet)
22	Axle 4 Right Side weight (kips)	Axle 4 Right Side weight (kips)
23	Axle 4 Left Side weight (kips)	Axle 4 Left Side weight (kips)
24	Spacing between Axles 3 & 4 (feet)	Spacing between Axles 3 & 4 (feet)
25	Axle 5 Right Side weight (kips)	Axle 5 Right Side weight (kips)
26	Axle 5 Left Side weight (kips)	Axle 5 Left Side weight (kips)
27	Spacing between Axles 4 & 5 (feet)	Spacing between Axles 4 & 5 (feet)
28	<unused>	<unused>
29	<unused>	<unused>
30	<unused>	<unused>
31	<unused>	<unused>
32	<unused>	<unused>
33	<unused>	<unused>
34	<unused>	<unused>
35	<unused>	<unused>
36	<unused>	<unused>
37	<unused>	<unused>
38	<unused>	<unused>
39	<unused>	<unused>
40	Direction	<unknown>
41	Axle number	<does not exist>

4.1.2 Data Conversion:

Raw data obtained from the WIM is in a binary format and cannot be analyzed directly. This raw data is converted to ASCII files using software provided by the two WIM vendors. The different types of information available from the WIM equipments are listed in Table 4.2. The data from Pat and IRD have 41 and 40 different fields respectively. The 40th field from IRD is unknown.

4.2 Analysis of data from WIM in California

This section describes the analysis of truck traffic data collected from January 1991 to March 2001, from all weigh-in-motion (WIM) stations on the California highway network. Over 100 WIM stations are installed on the California highway system as described in Section 4.1.

4.2.1 Types of Analysis:

The following tasks were performed:

1. Develop axle load spectra for various axle groups of each truck type and compare these load spectra among various locations and time periods
2. Determine truck traffic volume and load growth trends using regression methods
3. Characterize past truck traffic loading patterns, including truck speeds, gross weights and side wheel load differences
4. Check the possibility of extrapolation of available truck traffic data to sites where WIM stations are not installed.

4.2.2 Data Used for Analysis

Caltrans WIM stations collected and stored truck traffic information continuously once they were installed. Only on abnormal occasions would the data collection action be interrupted. These occasions included power failures, communication interruptions and pavement maintenance and rehabilitation activities.

Preliminary analysis of traffic data from 6 randomly chosen and well distributed Caltrans WIM stations showed a significant difference in traffic from weekdays to weekends and less significant differences across months. Based on this it was decided that the data from one week per month would be used for analysis.

The WIM office of Caltrans had checked one to two weeks' WIM data in each month for validity and kept the results in the WIM File Download Record. Two kinds of data were chosen as candidates for sampling:

1. Data collected from a system that was working well and that provided good data
2. Data collected from a system that had some minor errors but was generally considered acceptable.

When a continuous one week data set was not available, the following strategy was employed:

1. If good data for the same day was available from another week it was used
2. If less than 7 days of data were available in a month, 3 weekdays and 1 weekend data were used (to keep the ratio close to 2.5:1)

Due to the break down of WIM stations, system errors lasting several months, communication interruptions between WIM station and the WIM office and other reasons, a complete one week per month data set sample was rarely obtained for each WIM station.

4.2.2.1 Data Conversion

Raw data obtained from the WIM is in a binary format and cannot be analyzed directly and was converted to ASCII files using software provided by the two WIM vendors.

4.2.3 Vehicle Classification & Assumptions

Shown in Table 4.3 are the criteria for classifying different types of vehicles. Vehicle types 4 to 15 were considered in the analysis. The following assumptions were used in the analysis:

Assumption 1 - Axle Groupings:

1. Front axle is steering axle
2. 1.8 m separation was used to distinguish between single, tandem and tridem axles
3. Spacing of an axle with adjacent axles >1.8m – Single Axle
4. Spacing between 2 adjacent axles <1.8m and the spacing between the adjacent axles and these >1.8m – tandem axle
5. Spacing between 3 adjacent axles<1.8m and the others with these >1.8 – tridem axle

Table 4.3 WIM vehicle classification parameters

Type	Vehicle Description	# of Axles	Spacing (ft.)								Weight (kips)
			1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	Min.-Max.
1	Motorcycle	2	0.10-5.99								0.10-3.00
2	Auto, Pickup	2	6.00-9.99								1.00-7.99
3	Other (Limo, Van, RV)	2	10.00-22.99								1.00-7.99
4	Bus	2	23.00-40.00								12.00->
5	2D	2	6.00-22.99								8.00->
2	Auto W/ 1 Axle trailer	3	6.00-9.99	6.00-25.00							1.00-11.99
3	Other W/ 1 Axle trailer	3	10.00-16.00	6.00-25.00							1.00-11.99
4	Bus	3	23.10-40.00	3.00-5.99							20.00->
5	2D W/ 1 Axle trailer	3	6.00-23.09	6.00-25.00							12.00-19.99
6	3 Axle	3	6.00-23.09	3.00-5.99							12.00->
8	2S1,21	3	6.00-23.00	11.00-40.00							20.00->
2	Auto W/ 2 Axle trailer	4	6.00-9.99	6.00-25.00	1.00-11.99						1.00-11.99
3	Other W/ 2 Axle trailer	4	10.00-16.00	6.00-25.00	1.00-11.99						1.00-11.99
5	2D W/ 2 Axle trailer	4	6.00-23.09	6.00-25.00	1.00-11.99						12.00-19.99
7	4 Axle	4	6.00-23.09	3.00-5.99	3.00-12.99						12.00->
8	3S1, 31	4	6.00-23.00	3.00-5.99	13.00-44.00						12.00->
8	2S2	4	6.00-23.00	11.00-44.00	3.00-11.99						20.00->
3	Other W/ 3 Axle trailer	5	10.00-16.00	6.00-25.00	1.00-3.49	1.00-3.49					1.00-11.99
9	3S2	5	6.00-26.00	3.00-5.99	6.00-46.00	3.00-10.99					12.00->
11	2S12	5	6.00-26.00	11.00-26.00	6.00-20.00	11.00-26.00					12.00->
14	32	5	6.00-26.00	3.00-5.99	6.00-23.00	11.00-27.00					12.00->
10	3S2, 33	6	6.00-26.00	3.00-5.99	6.00-46.00	3.00-11.99	3.00-10.99				12.00->
12	3S12	6	6.00-26.00	3.00-5.99	11.00-26.00	6.00-24.00	11.00-26.00				12.00->
13	2S23, 3S22, 3S13	7	6.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00			12.00->
13	3S23	8	6.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00		12.00->
13	Permit	9	6.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	12.00->
15	Error and/or unclassified vehicles not meeting axle configurations set for classifications 1 through 14										

Assumption 2 - Defining Day & Night:

Day was defined as between 6 A.M. to 6 P.M. Night was defined as between 6 P.M. to 6 A.M.

Assumption 3 – The Three Seasons:

Wet season lasted from November to February.
Spring lasted from March to June
Dry lasted from July to October

Assumption 4 - Load Ranges:

- Steering & Single Axles – 0 to 220KN in 5KN intervals

- Tandem Axles – 0 to 440KN in 10KN intervals
- Tridem – 0 to 500KN in 10KN intervals

"Steering axle" means one or more axles on the front of a power vehicle that can be activated by the operator to directly accomplish guidance or steering of the power vehicle or a combination of vehicles.

4.2.4 Analysis

A Fortran Program was run on the ASCII data to obtain the following:

- The load spectra of the four axle groups (steering, single, tandem, and tridem) of different truck types at different times (i.e., day/night, season, year) and different locations (i.e., site, direction, and lane).
- The traffic volume distribution among different locations (i.e., site, direction, and lane) and at different times (i.e., day/night, season, and year)
- Truck traffic growth trends
- Side wheel load differences
- Truck speed distributions

The Load Spectrum Coefficient (LSC) was used to compare normalized Load Spectra. The LSC is defined as follows:

$$\mathbf{LSC} = \sum \left[\left(\frac{\text{mid-load\_range}_i / L}{80}\right)^m \times \frac{\text{load-range\_count}_i}{\text{total\_count}} \times L \right]$$

l =Number of load ranges
mid-load_range_i =Average load range (kN) for load range i
$\text{load\_range\_count}_i$ =Number of axles in load range i
L = 1 for steering axle and single axle, 2 for tandem, and 3 for tridem
m =exponent, 3.8

4.2.4.1 Load distribution across vehicle classes and by day and night

Both Load Spectra Diagrams and LSC were used to compare load distributions. Selected results obtained from this analysis are show in Fig 4.2, 4.3 and 4.4.

Results: Truck types 5, 6, 8, 9, and 11 account for an average of 90% of all the truck traffic. In general, the trucks operating at night are heavier than those operating during the day.

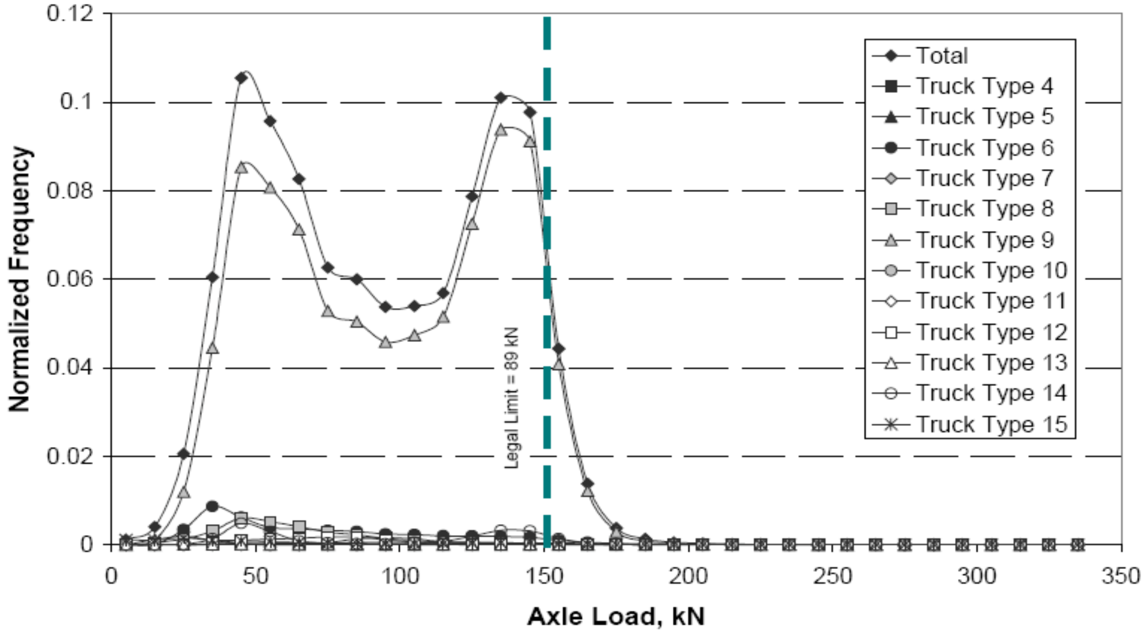

Fig 4.2 General Tandem Axle Spectra Across All Dates and Locations

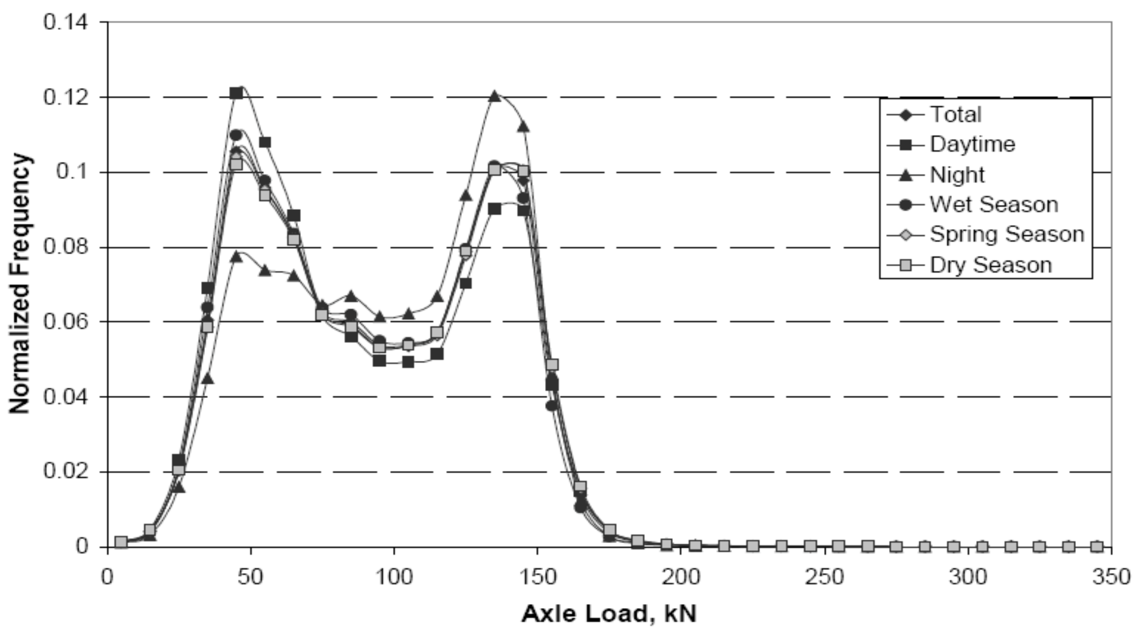

Fig 4.3 General Tandem Axle Load Spectra at Different Times

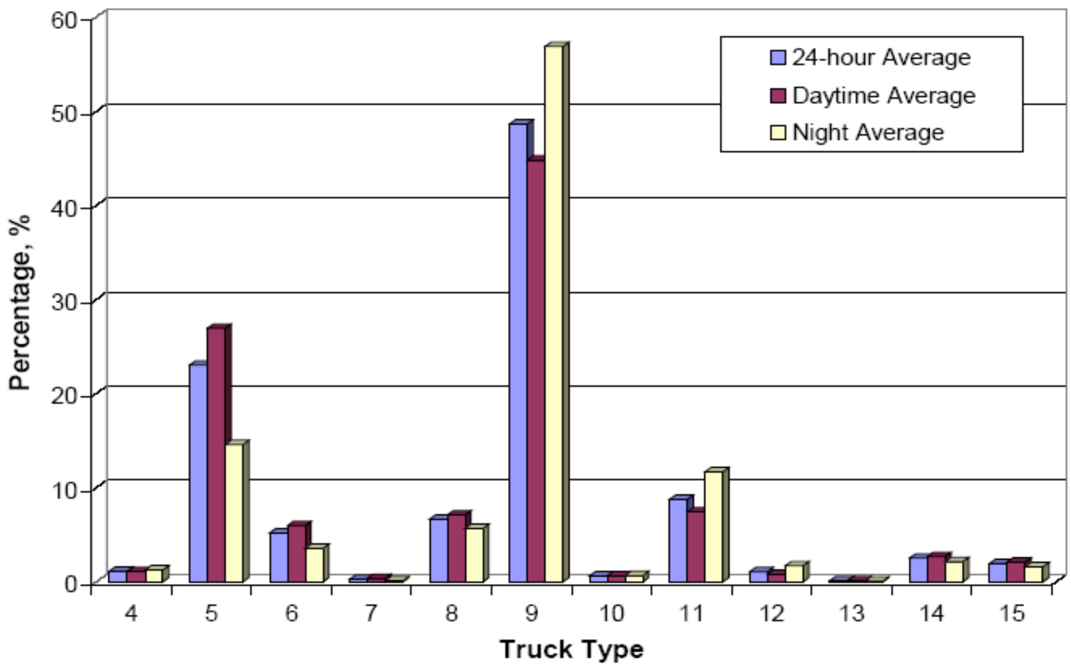

Fig 4.4 General Truck Traffic Composition (Day, Night and 24 Hour)

4.2.4.2 Grouping into three regions and by rural and urban:
The sites were divided into three groups based on following three locations - Central Valley, Bay Area and Southern California. The sites were also classified as rural and urban. The distributions are shown in Table 4.4. Subsequent analysis was done to compare these groups. Several interesting observation were made.

Table 4.4 WIM Station Location Groupings

Geographical Region	WIM Station No.
Central Valley	2, 10, 20, 28, 30, 49, 72, 99
Bay Area	1, 3, 4, 7, 11, 17, 18, 24, 27, 29, 31, 32, 33, 34, 35, 36, 41, 42, 44, 45, 46, 50, 51, 52, 55, 56, 57, 58, 64, 68, 71, 75, 81, 86, 93, 94
Southern California	5, 8, 9, 12, 13, 14, 15, 16, 21, 22, 23, 25, 26, 37, 38, 39, 40, 43, 47, 48, 53, 54, 59, 60, 61, 62, 63, 65, 66, 67, 69, 70, 73, 74, 76, 77, 78, 79, 80, 82, 83, 84, 85, 87, 88, 89, 90, 91, 92, 95, 96, 97, 98
Type of Area	**WIM Station No.**
Rural	7, 20, 21, 22, 23, 25, 26, 27, 28, 30, 35, 36, 40, 43, 44, 45, 49, 66, 71,72, 73, 76, 86, 93, 94, 99
Urban	1, 2, 3, 4, 5, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 24, 29, 31, 32, 33, 34, 37, 38, 39, 41, 42, 46, 47, 48, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 67, 68, 69, 70, 74, 75, 77, 78, 79, 80, 81, 82, 83, 84, 85, 87, 88, 89, 90, 91, 92, 95, 96, 97, 98

Results: The typical results for the case of tandem axles are shown in Fig 4.5 and Fig 4.6. It should be noted that in general the load spectra for the Central Valley is slightly higher than that for the Bay Area and Southern California; and for the rural group is higher than that for the urban group.

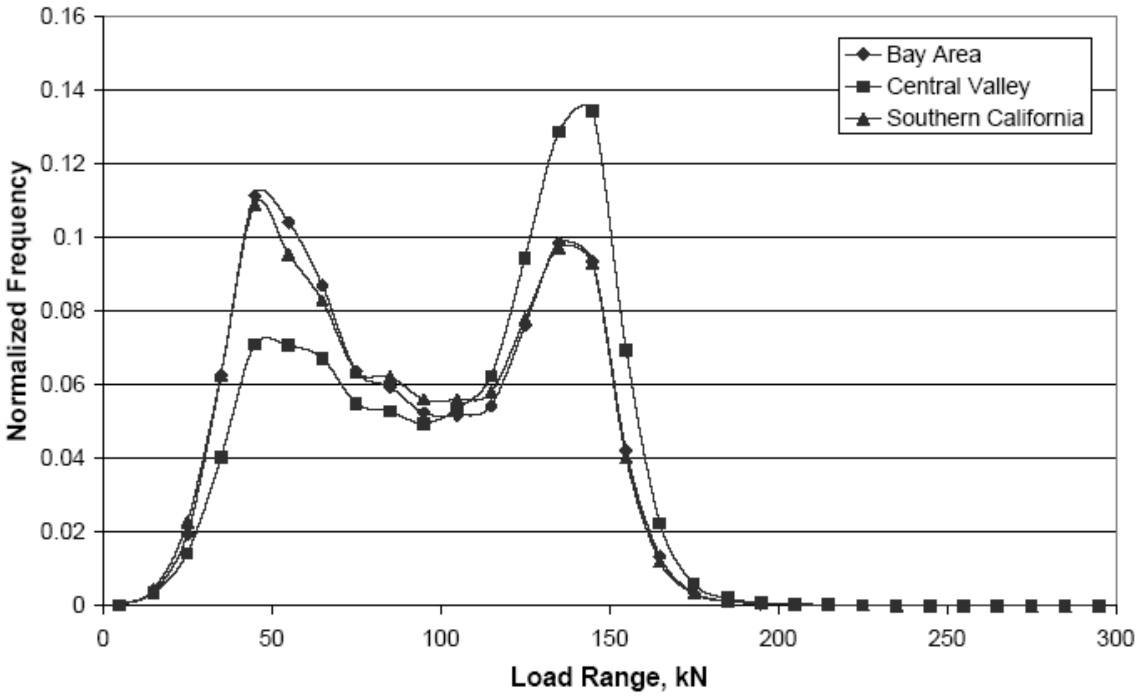

Fig 4.5 Tandem Load Spectra in the Three Regions

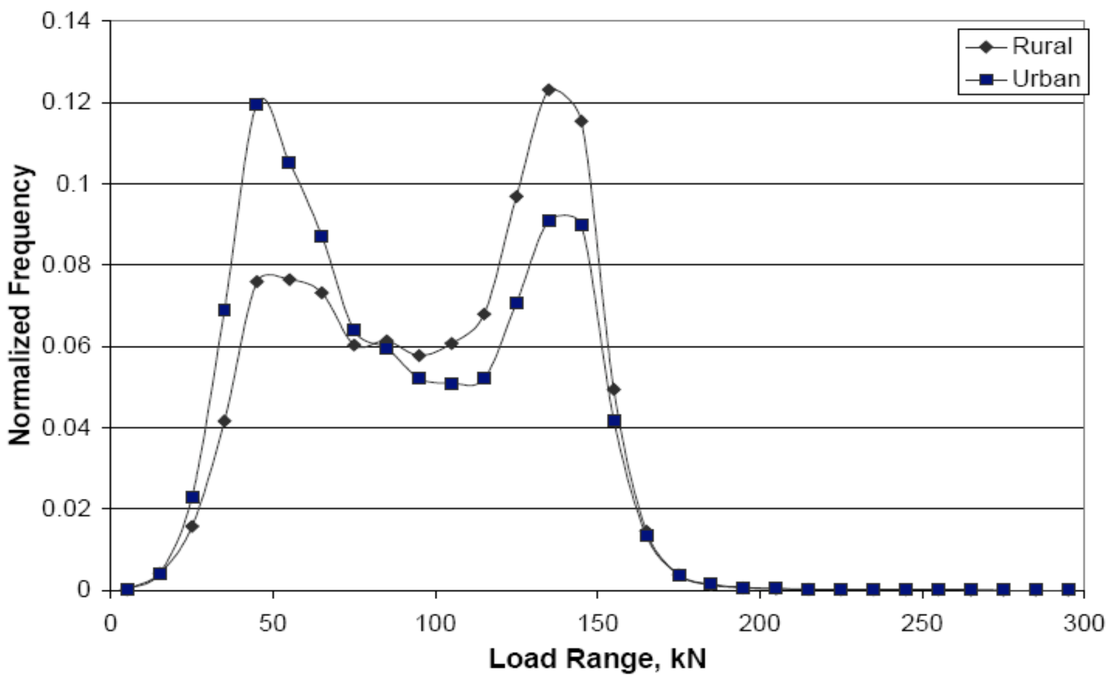

Fig 4.6 Tandem Load Spectra Distribution (Rural and Urban)

4.2.4.3 Analysis of sites (6 sites) representative of all 3 regions (Central Valley, Bay Area and Southern California) by rural and urban and by the two directions of travel

The six sites are listed in Table 4.5.

Table 4.5 Six WIM Sites as Representative Examples

Site No.	WIM Station No.	Location Information					Direction	Area [1]
		Name	District	County	Route	Postmile		
1	2	Redding	2	Shasta	5	R24.9	SB/NB	CV/U
2	17,18	Hayward	4	Alameda	880	14.7	SB/NB	BA/U
3	21	Mojave	6	Kern	58	108.1	WB/EB	SC/R
4	47,48	Castaic	7	Los Angeles	5	R56.1	SB/NB	SC/U
5	57,58	Pinole	4	Contra Costa	80	7.5	WB/EB	BA/U
6	72	Bowman	3	Placer	80	23.4	WB/EB	CV/R

[1] CV-Central Valley; BA-Bay Area; SC-Southern California; U-Urban; R-Rural.

Typical findings for a site (Redding) are shown in Fig 4.7

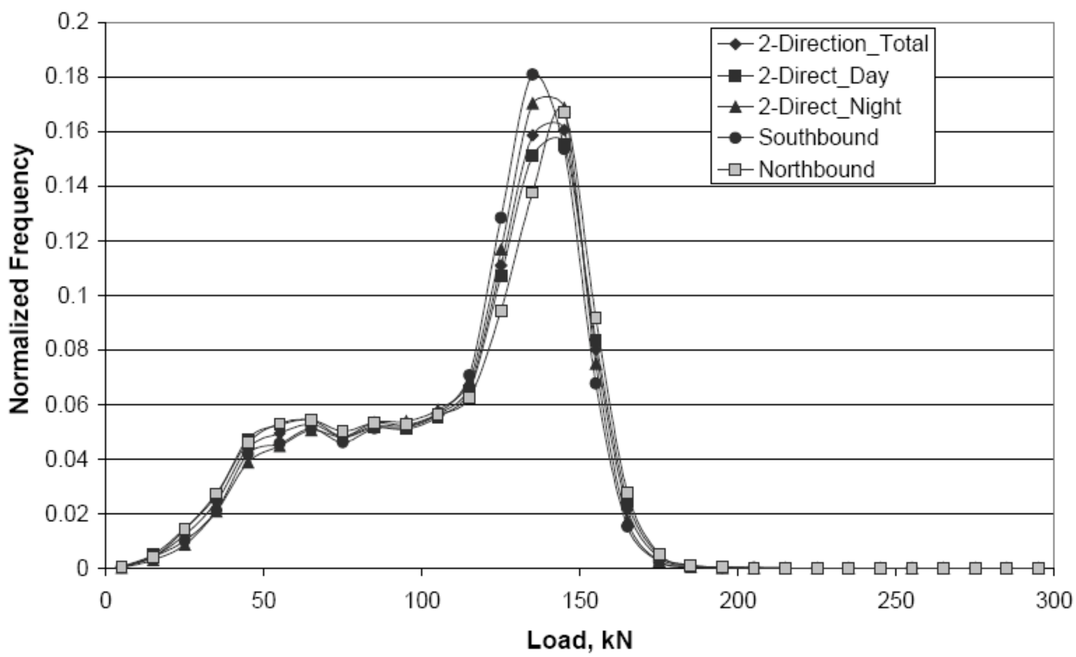

Fig 4.7 Axle Load Spectra, Station 2 (Redding), Tandem Axle

Results: It was found in general that the load spectra shift towards the heavier side during the night and is dependant on the direction of travel for each location.

4.2.4.4 Lane wise distribution

A typical situation is shown in Fig 4.8. One can conclude that the weight distribution is almost identical for the same lane number in both directions of travel. The weight increases as one moves outwards from the innermost lane.

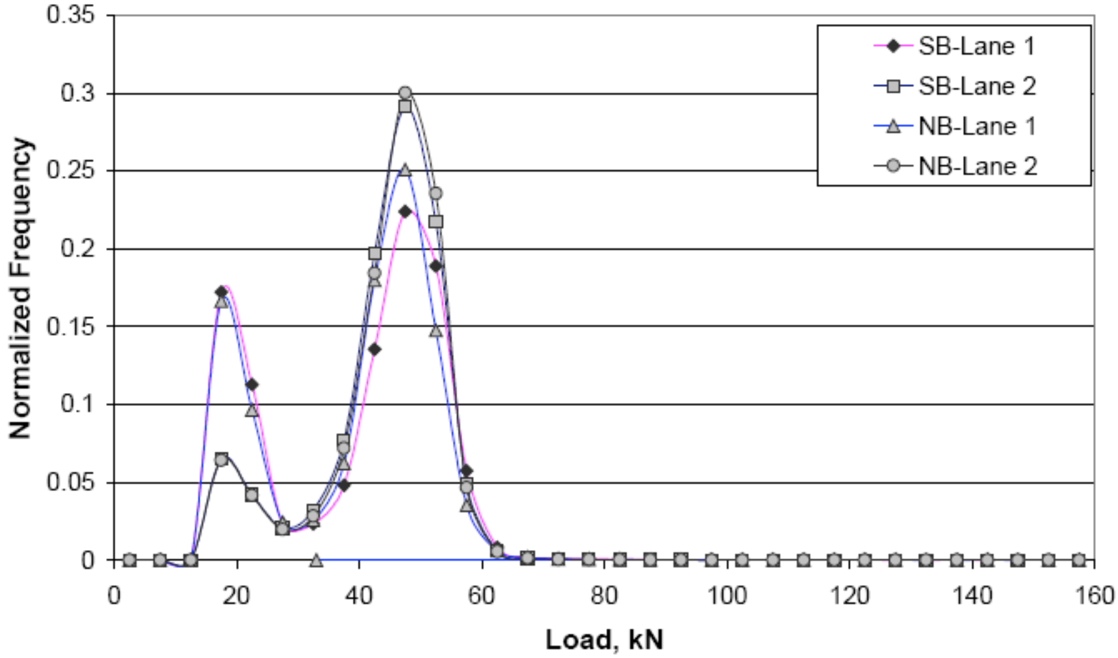

Fig 4.8 Axle Load Spectra by Lane, Station 2 (Redding), Steering Axle

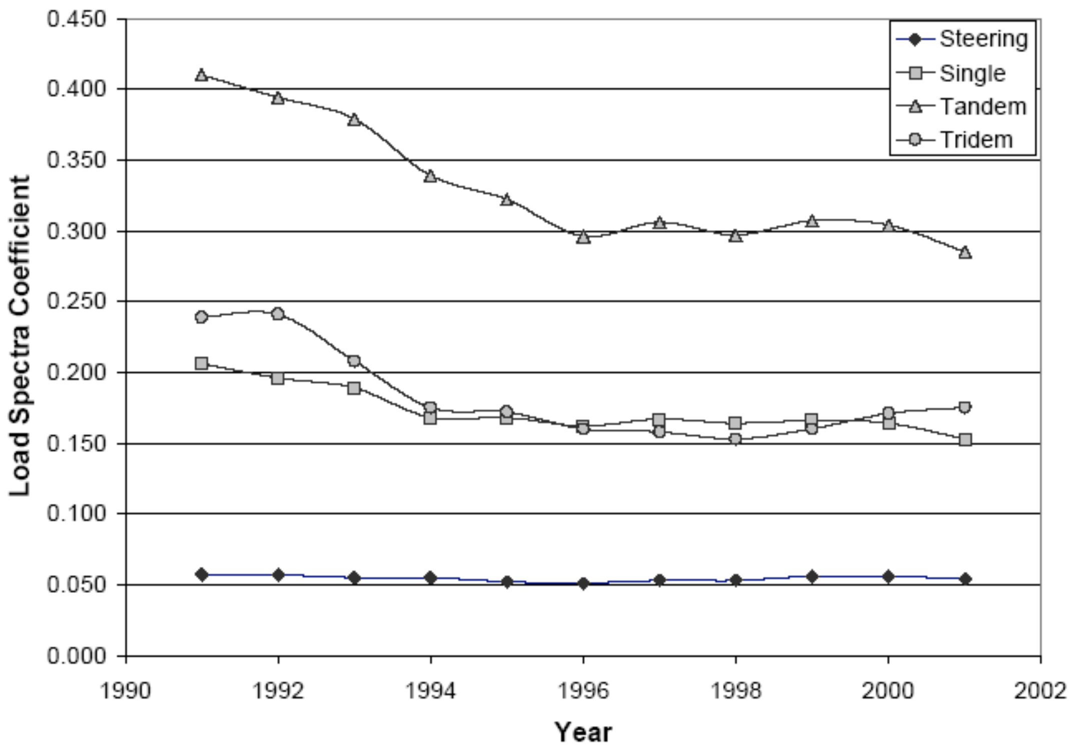

Fig 4.9 General Load Spectra Coefficients Across All Stations in California in Each Year: 1991-2000

4.2.4.5 Year-wise Distribution: Growth trends

As shown above in Fig 4.9, the weight of the trucks decreased up to 1995 and then became stable.

4.2.4.6 Volumes by Direction:

Direction doesn't appear to be a major factor in the truck distributions for the cases studied. Shown in Fig 4.10 is a typical case of the percentage of trucks in northbound and southbound traffic over different classes.

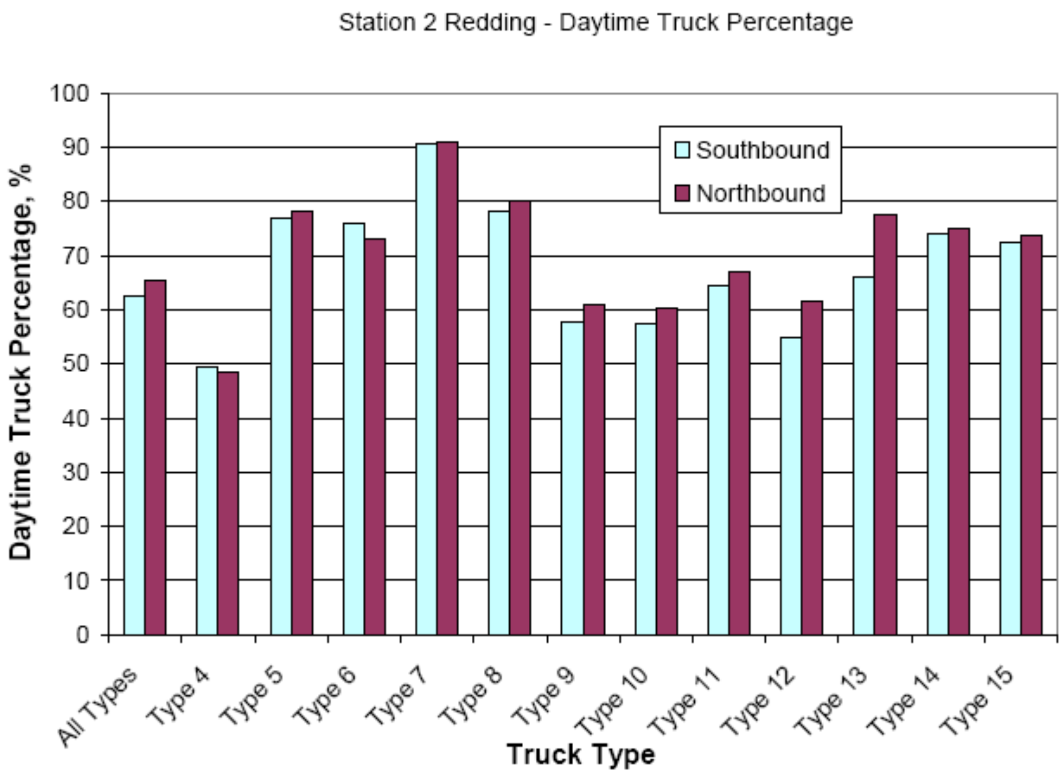

Fig 4.10 Percentage of Trucks Operating in the Daytime, Station 2 (Redding)

4.2.4.7 Seasonal Distribution

Very little variation by season was observed. Fig 4.11 represents a typical case.

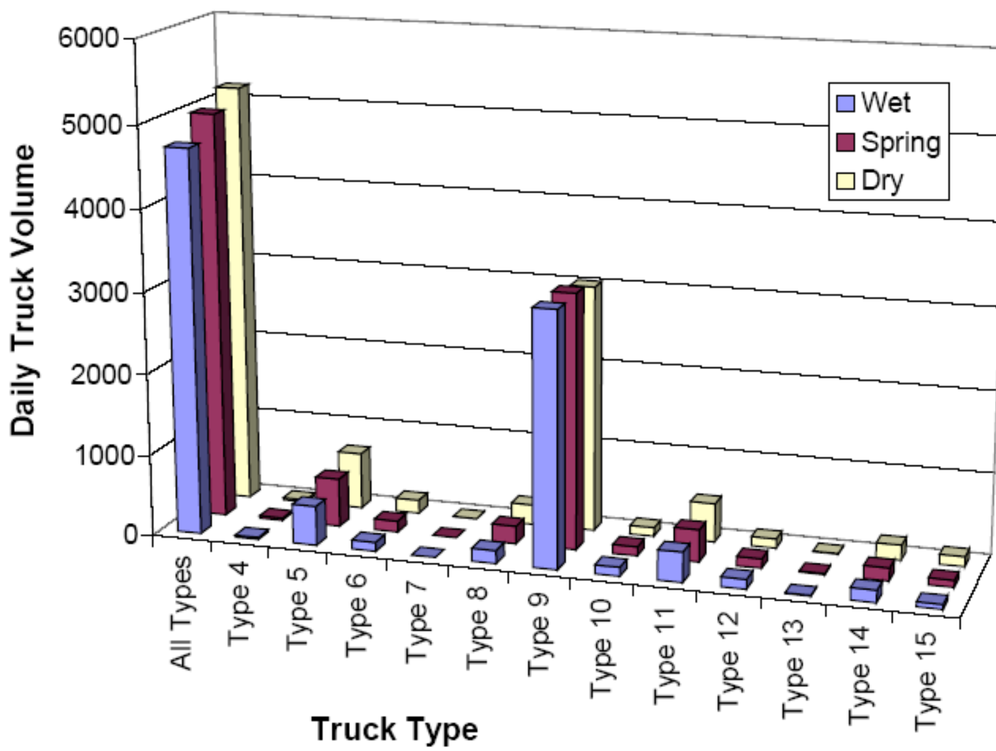

Fig 4.11 Seasonal Average Daily Truck Volume (Both Directions), Site 1 (Station 2, Redding)

4.2.4.8 Distribution by Lane

The common observation was that 90% of the truck traffic flow is in the outermost lane when there are two lanes. In cases of more than two lanes, 90% of the truck traffic flow is in the two outermost lanes. The scenario is depicted below in Fig 4.12 and 4.13

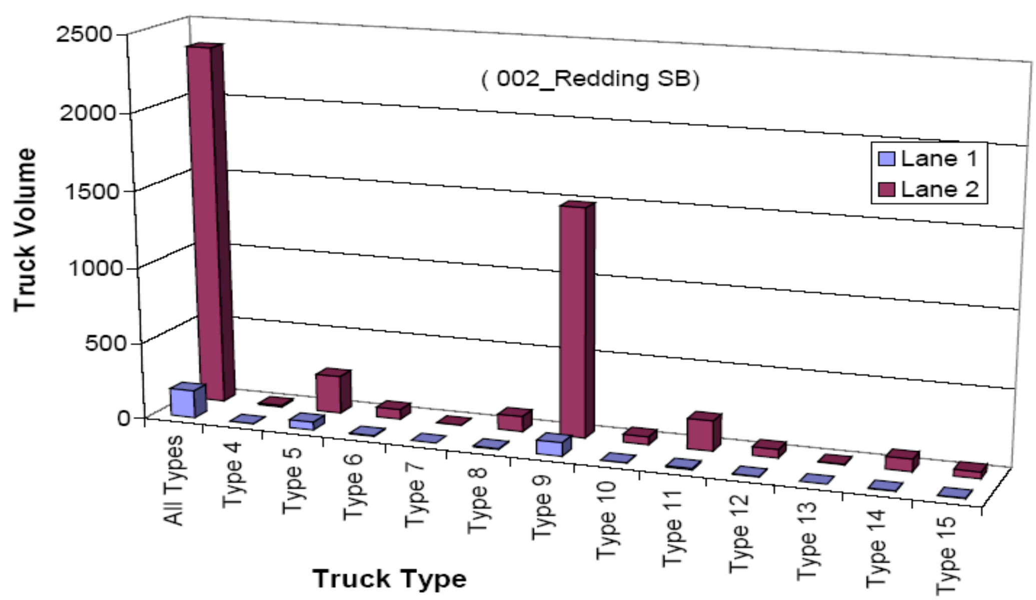

Figure 4.12 Typical Truck Traffic Distribution by Lane (2 lanes)

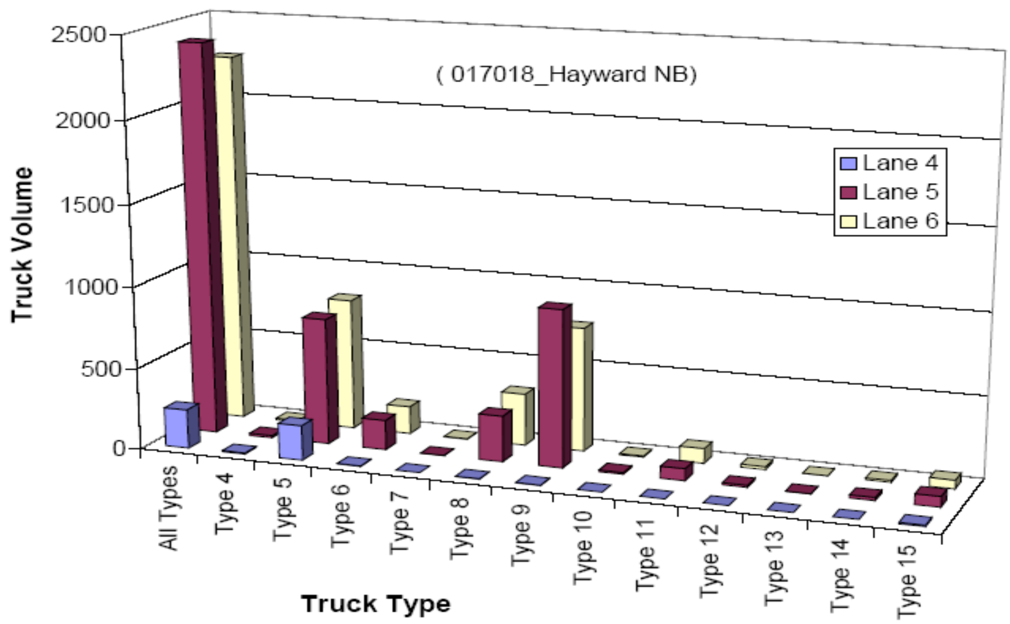

Fig 4.13 Typical Truck Traffic Distribution by Lane (3 Lanes)

4.2.4.9 Truck Traffic Growth Analysis

Linear as well as nonlinear regression models were examined on the net truck traffic volume across all WIM stations as a function of year. The result obtained was of the following form:

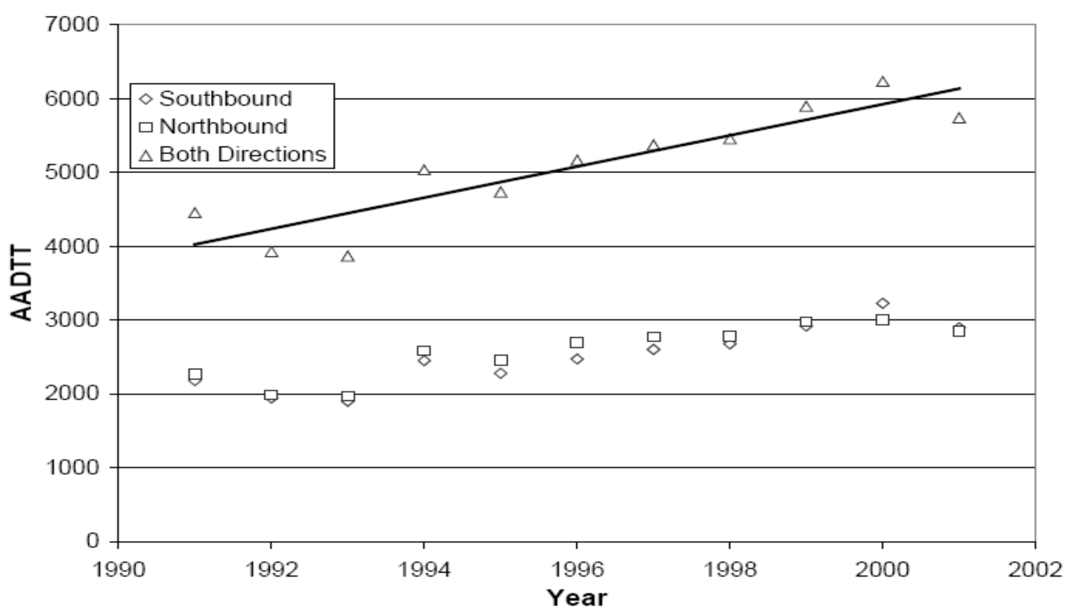

Fig 4.14 Linear Regression Model for Truck Traffic Growth

The nonlinear model was of the following form:

$$AADTT = b_0 \times (1 + b_1)^{(year-1990)}$$

4.2.4.10 Side Wheel Load Difference Analysis
Side Wheel Load Difference Ratio

$$SWLDR = \left(L_{right} - L_{left}\right) / \left(L_{right} + L_{left}\right) \times 100\%$$

Where
L_{right} = Right side wheel load in KN
L_{left} = Left side wheel load in KN

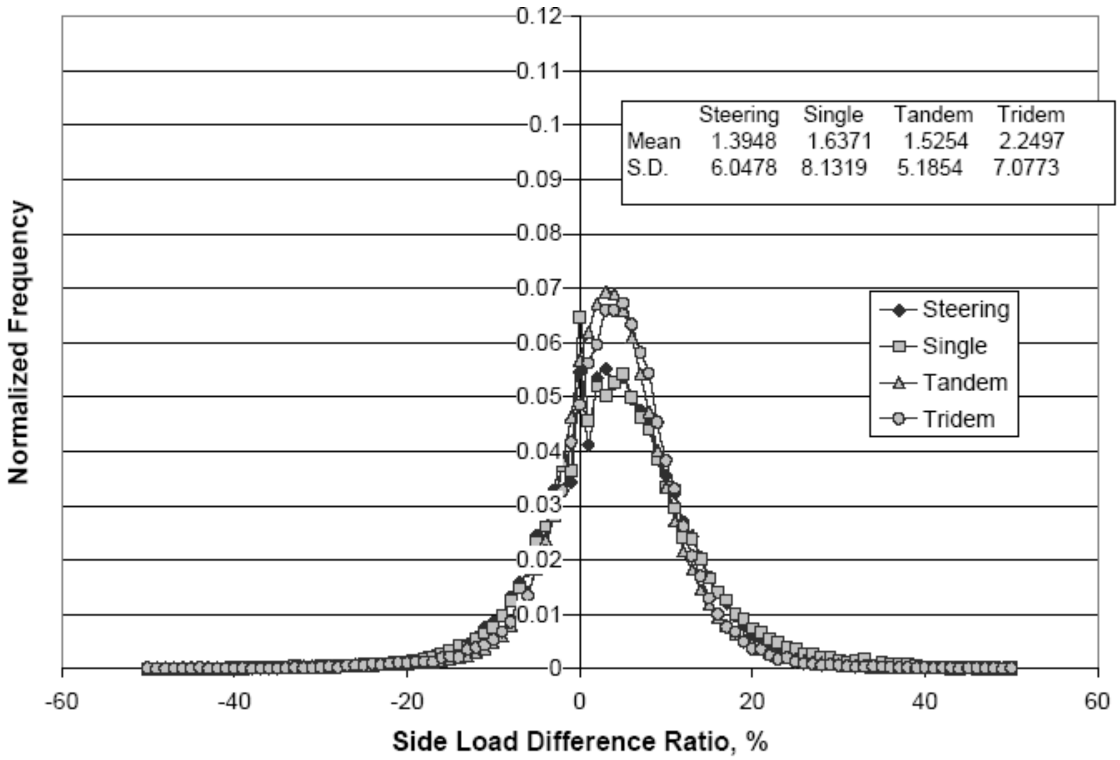

Fig 4.15 Side Wheel Load Difference Ratio Distribution for Site 1 (Station 2, Redding), Southbound

The typical result is shown in Fig 4.15. In general, the right wheel load is slightly higher than the left wheel load, mainly due to transverse slope. The mean is between 0 and 3%, which is not alarmingly high.

4.2.4.11 Truck Speed Analysis
It was found that there was not much variation with direction and most speeds were found to be between 80km/h and 96km/hr. This situation is depicted in Fig 4.16 and Table 4.6.

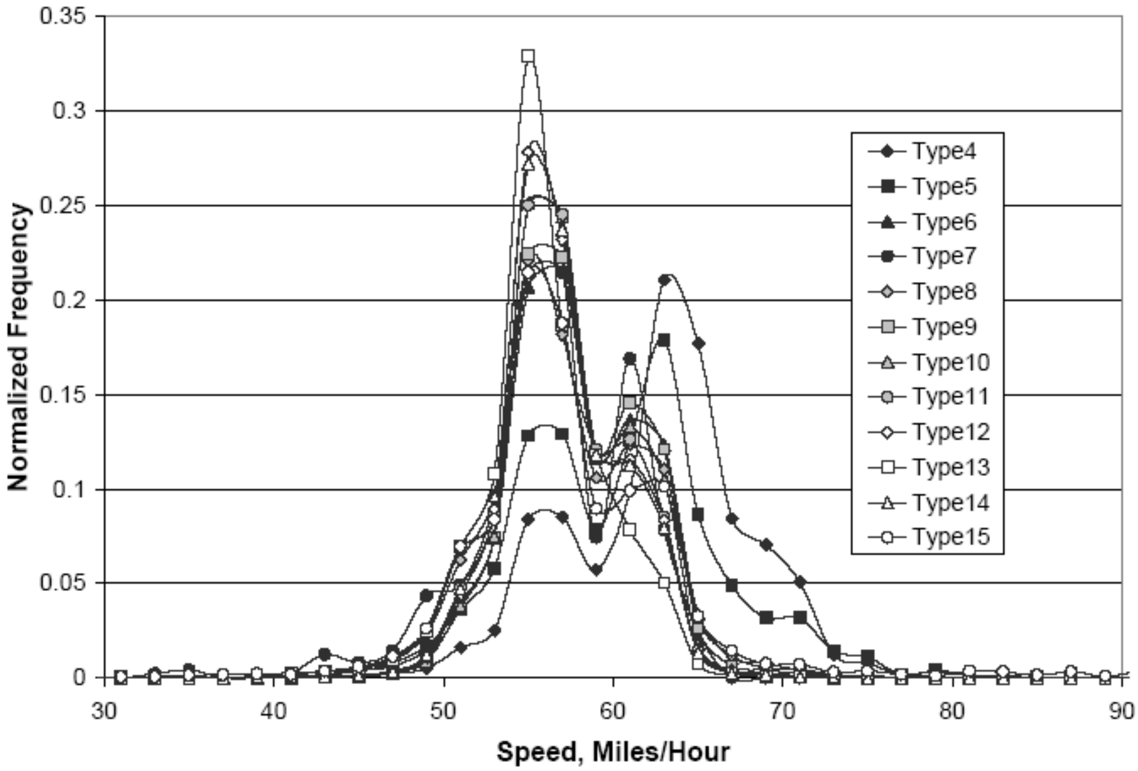

Fig 4.16 Speed Distribution of Each Truck Type at Site 1 (Station 2, Redding), Southbound

Table 4.6 Average Speed of Each Truck Type at 6 WIM Sites

Station No.	Location	Direction	Speed by Truck Type (km/h)											
			4	5	6	7	8	9	10	11	12	13	14	15
2	Redding	Southbound	103	97	93	90	92	93	92	92	92	90	92	92
		Northbound	103	97	92	87	90	93	92	92	92	89	92	92
17 & 18	Hayward	Southbound	92	87	85	84	85	85	85	85	87	77	87	76
		Northbound	89	84	82	80	82	82	80	84	82	79	84	77
21	Mojave	Westbound	92	87	87	76	84	84	82	76	79	66	84	84
		Eastbound	97	92	93	89	90	92	90	92	92	85	90	90
47 & 48	Castaic	Southbound	101	93	92	85	90	90	90	92	92	85	90	89
		Northbound	100	93	90	84	90	90	90	90	90	84	90	90
57 & 58	Pinole	Westbound	89	85	80	74	80	80	80	79	79	71	77	77
		Eastbound	95	90	87	85	89	89	87	89	89	84	87	84
72	Bowman	Westbound	109	106	101	97	100	101	101	103	103	98	98	95
		Eastbound	105	105	100	95	97	95	95	93	95	93	93	92

4.2.4.12 Truck Gross Weight Distribution

The legal maximum gross vehicle weight in California is 355 KN (80,000 lbs.). In most cases the majority of the trucks are found to be within the weight limits. A typical distribution is shown in Fig 4.17.

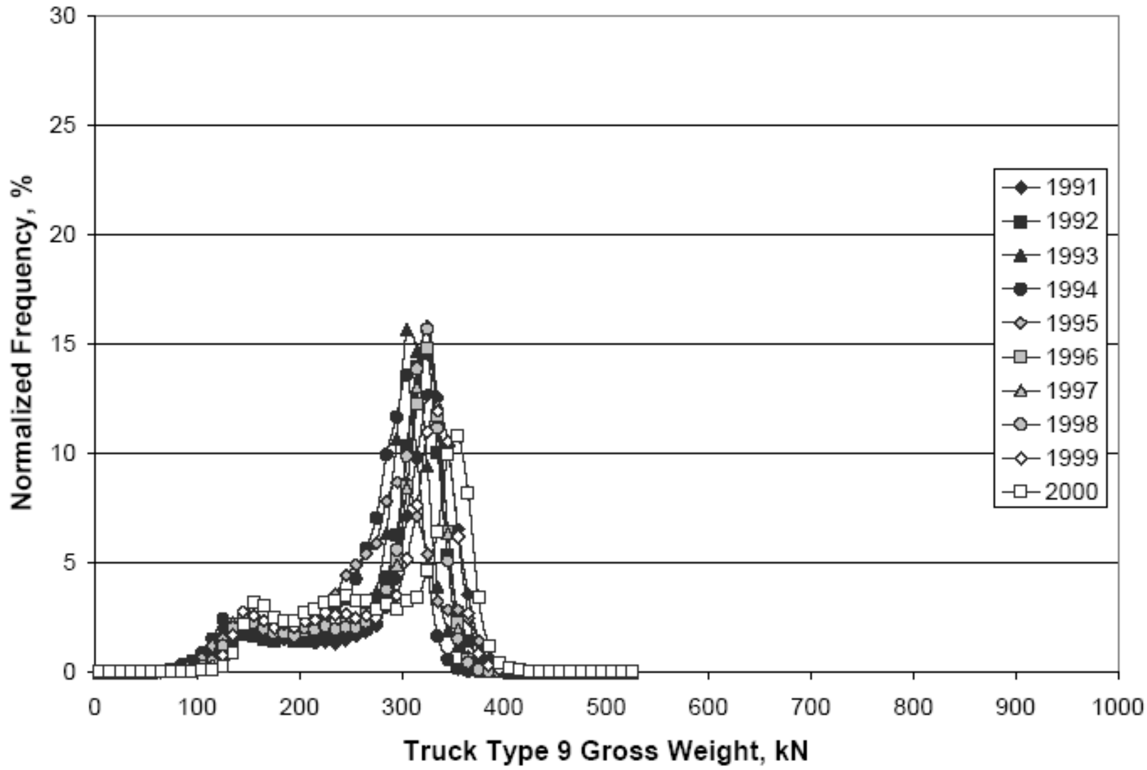

Fig 4.17 Truck Gross Weight Distribution for Truck Type 9 at Site 1 (Station 2, Redding), Northbound

4.2.4.13 Extrapolation of data between sites

The possibility of extrapolating the truck traffic volume and axle load spectra to new sites based on their location was investigated. Six groups were formed (as shown in Table 4.7 and Fig 4.18). All analysis was performed on data from these chosen sites to verify the degree of correlation and the possibility of extrapolations.

Table 4.7 Six WIM Station Groups Compared

Group No.	WIM Stations Included
1	20, 86, 93
2	2, 28, 30
3	21, 73, 74
4	25, 66, 71
5	43, 76, 95
6	22, 23, 26

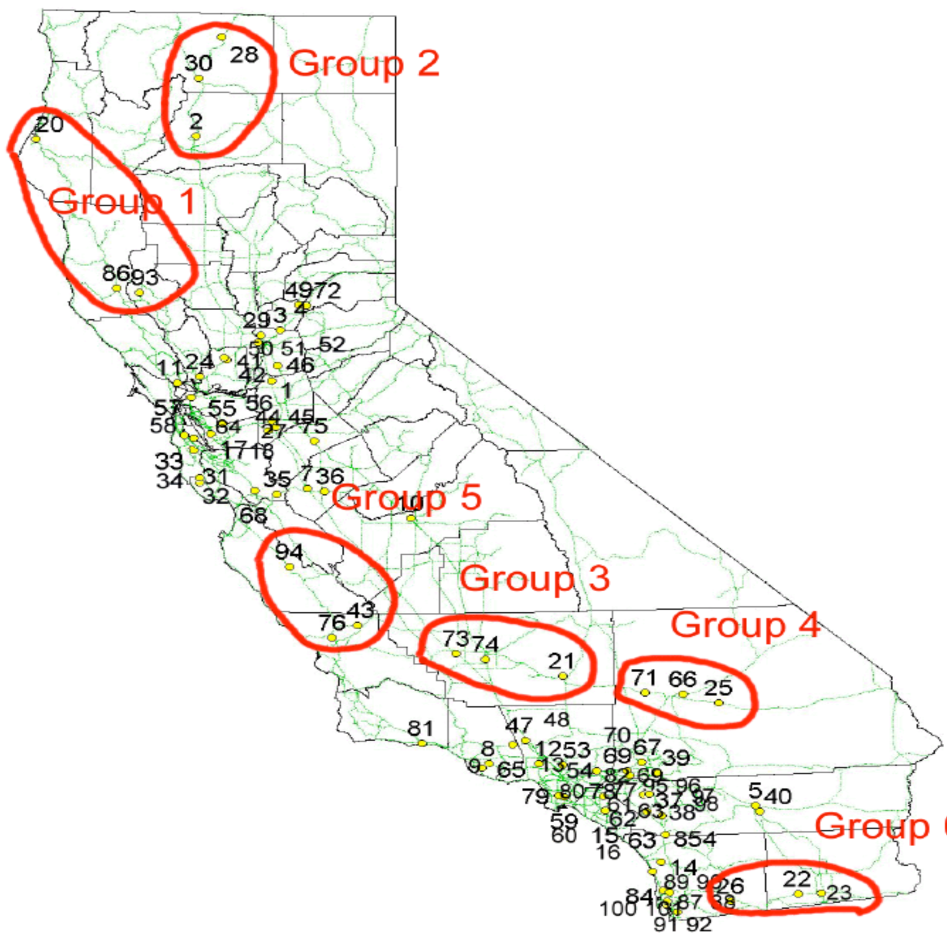

Fig 4.18 The Six WIM Station Groups used for Comparison

The results of the comparison are shown below in Fig 4.19 and Table 4.8

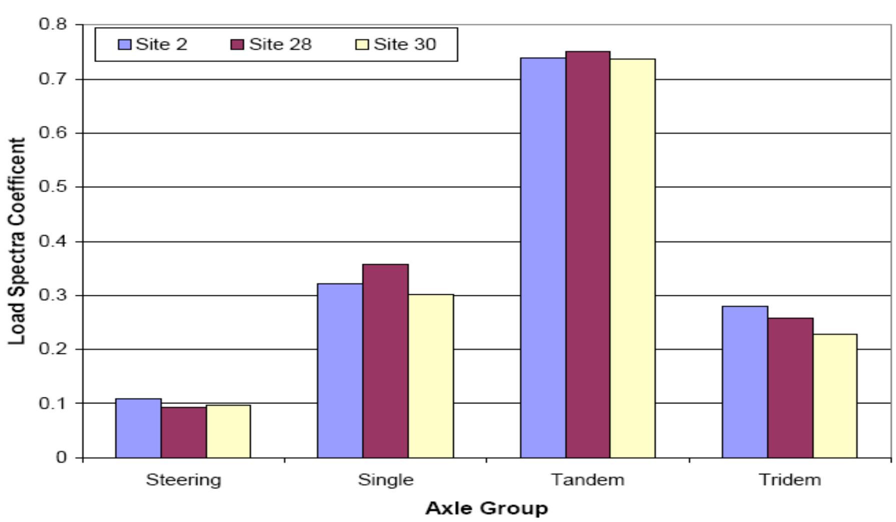

Figure 4.19 Comparison of Load Spectra Coefficients from Group 2

Table 4.8 Load Spectra Coefficient and AADTT of Six WIM Station Groups

Group	WIM Station	Load Spectra Coefficient				AADTT
		Steering	Single	Tandem	Tridem	
1	Station 20	0.083	0.300	0.863	0.190	1446
	Station 86	0.079	0.303	0.739	1.912	2057
	Station 93	0.050	0.185	0.446	0.161	561
2	Station 2	0.108	0.322	0.739	0.279	6234
	Station 28	0.094	0.357	0.751	0.258	1054
	Station 30	0.098	0.301	0.737	0.229	5689
3	Station 21	0.078	0.295	0.615	0.267	5443
	Station 73	0.111	0.300	0.532	0.214	7604
	Station 74	0.087	0.288	0.405	0.172	8529
4	Station 25	0.101	0.340	0.738	0.339	5824
	Station 66	0.107	0.342	0.589	0.238	6584
	Station 71	0.114	0.334	0.746	0.222	3784
5	Station 43	0.070	0.271	0.545	0.200	1782
	Station 76	0.068	0.242	0.465	0.202	3616
	Station 94	0.085	0.208	0.487	0.215	3123
6	Station 22	0.067	0.213	0.405	0.279	1666
	Station 23	0.072	0.241	0.429	0.270	3217
	Station 26	0.079	0.175	0.394	0.289	1811

Results: The load spectra coefficient judiciously can be extrapolated between similar sites. However, the AADTT cannot be extrapolated between similar sites as large variations appear among each group.

4.2.5 Recommendations

The following were the main recommendations made in the report "Truck Traffic Analysis using Weigh-In-Motion (WIM) Data in California by Harvey et al. (2002)**.**

1. Caltrans should start using WIM data in pavement design.
2. The two WIM vendors need to be contacted to find an improved method for identifying and modifying erroneous records to increase the accuracy of WIM data.
3. Adequate resources need to be provided to perform quality assurance checks at all WIM stations and to maintain them as needed. The high quality of the WIM data is dependent upon the WIM devices being routinely checked, calibrated, and maintained.

5: Virtual Weigh Stations in California: Cost-Effectiveness Analysis

This analysis quantifies an estimate of the benefits to the highway pavements in California from the potential use of VWS. The methodology used consists of the following:

1) Determining the damage currently caused by overweight trucks and
2) Modeling the potential pavement life saved with VWS.

The data used for the analysis was obtained from the Caltrans WIM database, year 2001. (Harvey et al. 2002).

Specific Objectives

- Estimate pavement damage caused by overweight trucks on the network.
- Estimate costs of this pavement damage to Caltrans.
- Estimate potential savings induced by the installation of VWS.

Below are the current California state law weight limits.

Weight Limits

- Steering and Single: 89 KN.
- Tandem: 151 KN.
- Tridem: 233 KN.

ESALs

ESAL is used as a reasonable indicator of expected average pavement damage. Each pass of an axle is converted to an ESAL based on the weight of the axle. This method, widely used in pavement design, is used so that different axle types can be summed together. The pavement service life is inversely proportional to the number of ESALs carried on a given highway segment.

$$ESAL = \alpha \left[\frac{\left(\frac{Weight}{\alpha} \right)}{80kN} \right]^{4.2}$$

α = number of individual axles in an axle group
For steering and singles, α = 1
For tandems, α = 2
For tridems, α = 4

Figure 1 shows the relation between ESALs and axle weight.

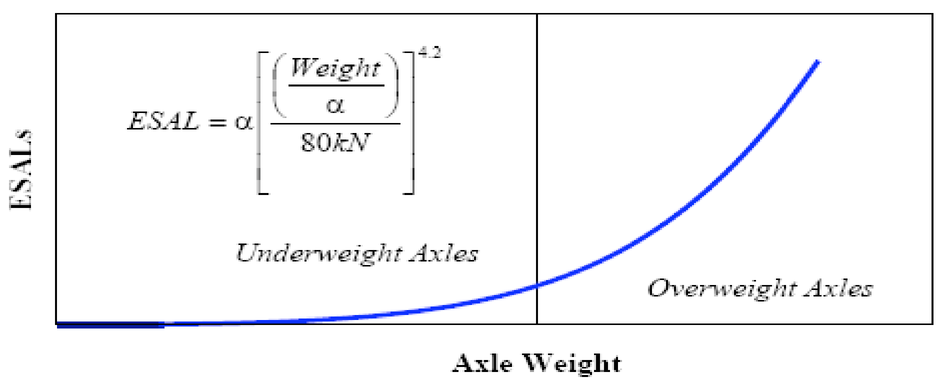

Figure 1. Plot of ESALs Versus Axle Weight (Harvey et al. 2002)

Methodology

1) ESALs were computed by using the general axle load spectra for all WIM locations and all dates from the year 2001 (Harvey et al. 2002).
2) Four general axle load spectra were considered: steering, single, tandem and tridem.
3) The ESALs were computed for the legal portion of the spectra and the overweight portion.
4) Using California's truck composition and number of axles depending on truck type, a factor for every axle type was calculated.
5) Using the same composition, the overweight ESALs were re-distributed to the weight limit (ex. for single axles, 89kN).
6) The costs incurred on the highway network were taken to be the average of the three fiscal years 2000-2003 (Harvey et al. 2002).
7) The costs are assumed to be proportional to the ESALs.
8) Savings are computed by reduction of ESALs due to enforcement.

Cost of Pavement Damage from Overweight Trucks

To define a monetary value for pavement damage, two assumptions are made:

1) Existing WIM sites represent traffic across the entire state.
2) Damage to pavement is estimated using the total maintenance and rehabilitation costs from the Caltrans 2003 "State of the Pavement" report.

Pavement maintenance and rehabilitation costs to Caltrans for each year were estimated. As an estimate of the cost of the damage per year to California pavements, we took the average of three fiscal years, 2000-2003: $500 million (Harvey et al. 2002).

Potential Savings from Virtual Weigh Stations

The potential savings resulting from this analysis are based on the following assumptions:

- Level of enforcement is 100%.
- Installation or operational costs are not considered.
- Virtual overweight trucks are considered to travel at the legal limit.

Results

In Table 1 the computed ESALs are presented, considering the truck type distribution.

Appendix A. Table1. ESALs for California Pavements

Type	Legal ESAL	Illegal ESAL	Total ESAL	ESAL after enforcement
Steering	0.0172	0.0000	0.0172	0.0172
Single	0.0333	0.0029	0.0362	0.0355
Tandem	0.2259	0.0845	0.3104	0.2912
Tridem	0.0010	0.0001	0.0011	0.0011
TOTAL	**0.2774**	**0.0874**	**0.3649**	**0.3449**

From the ESAL before the VWS enforcement, and the ESAL after enforcement, the expected benefits are computed; the results are presented in Table 2.

Table2. Expected Savings (millions of $)

In millions of $	
Total Cost	500.0
Cost/ESAL (k)	1370.4
Illegal Cost	119.8
New Cost	472.7
Savings	27.3
%Savings	5.46

Conclusions

Assuming that the estimated ESALs are equivalent to the pavement damage across the state network, 5.46% of the maintenance and rehabilitation costs can be saved. The enforcement of the weight limit with the Virtual Weight Stations would produce approximately $27.3 million in savings.

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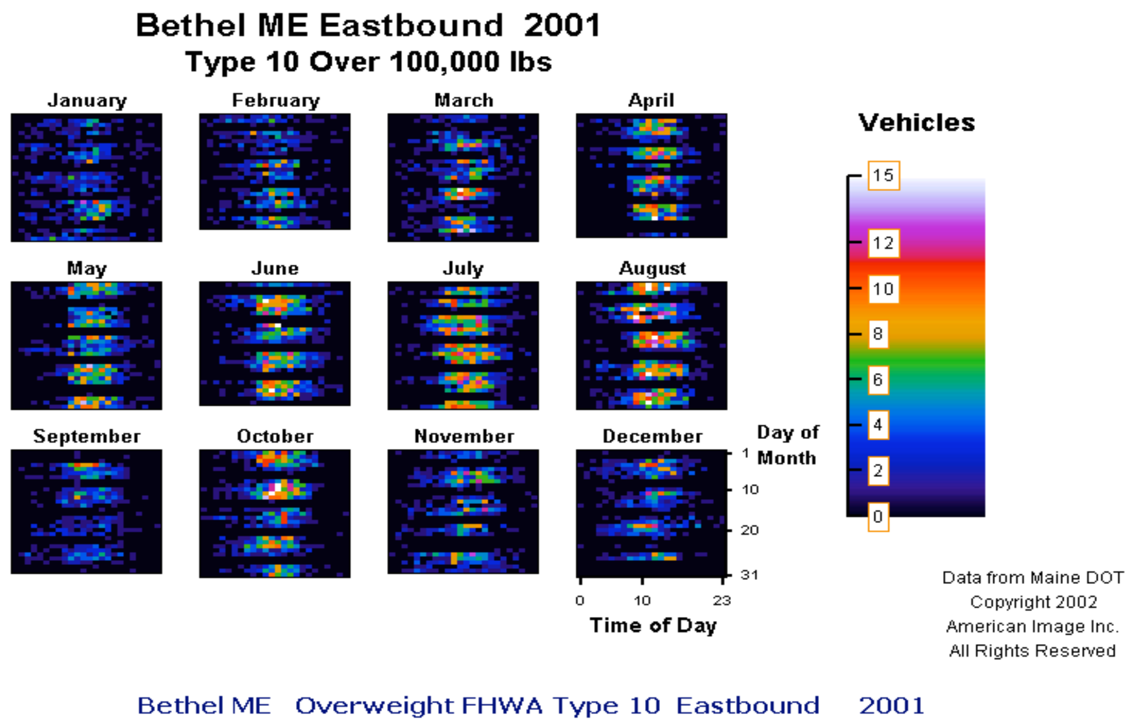


Fig 1 Total number of overweight (exceeding 100,000 lbs) eastbound FHWA Type 10 (3-axel trailer) trucks passing the WIM sensor in Bethel, Maine for every hour in 2001.

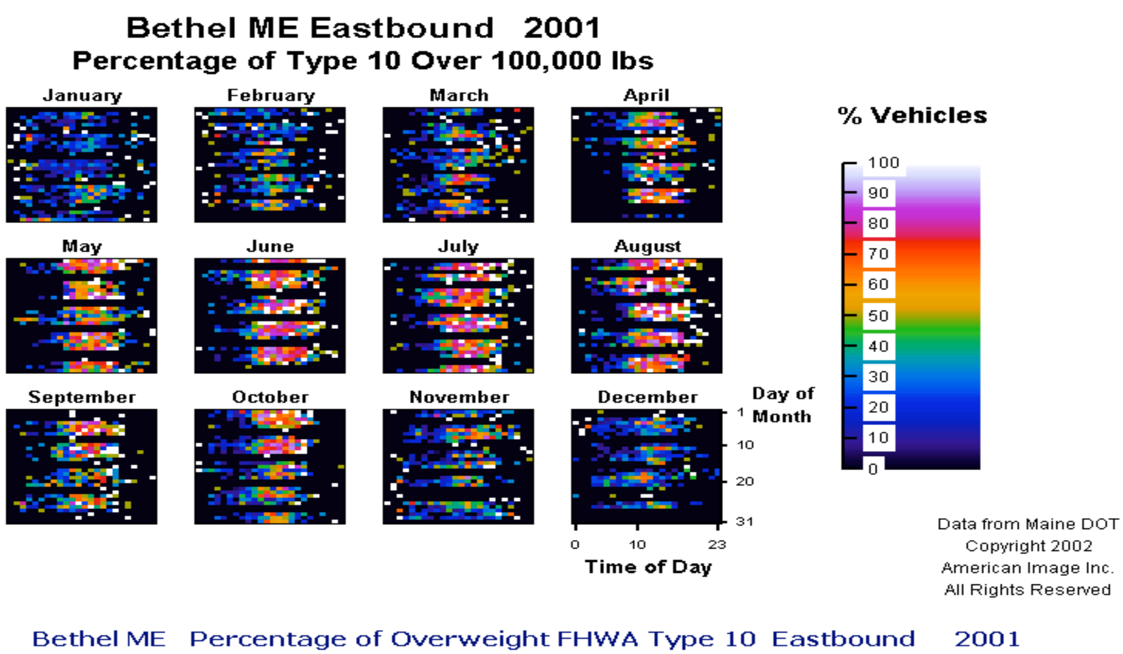
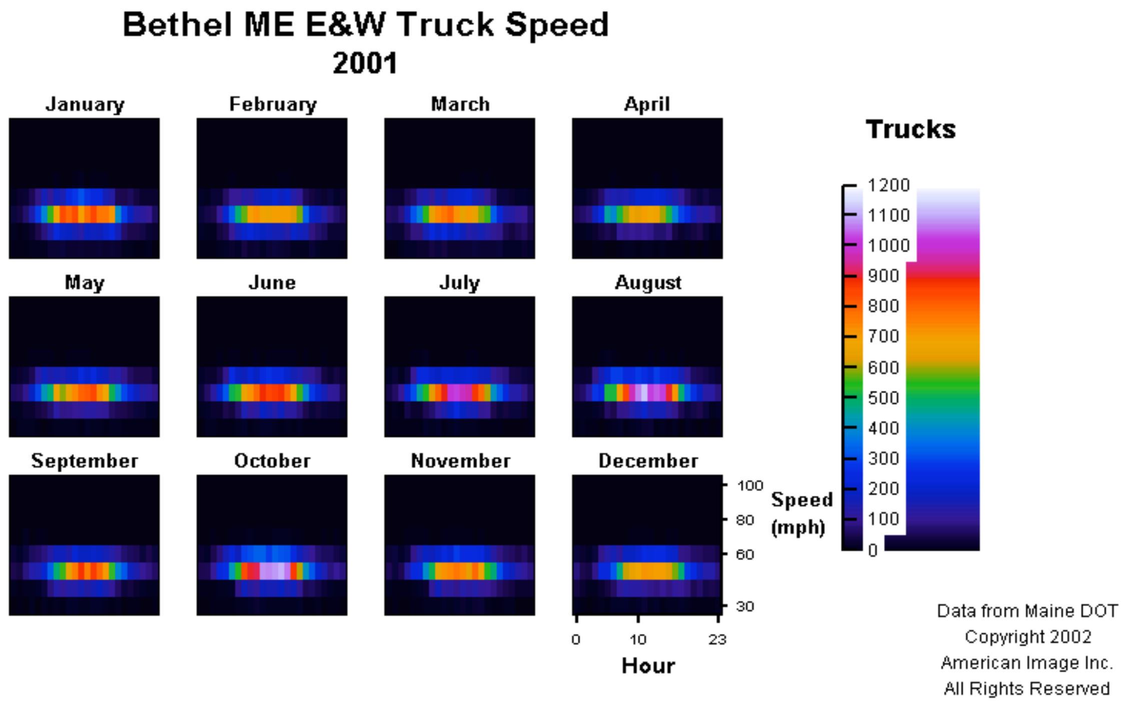


Fig 2 Percentage of eastbound overweight (exceeding 100,000 lbs) FHWA Type 10 (6-axle) trailer trucks passing the WIM sensor in Bethel, Maine for every hour in 2001.



Bethel Maine E & W Truck Speed 2001

Fig 3 Total number of trucks (FHWA Types 4-14) at each speed passing the WIM sensor in Bethel, Maine for all of 2001.

APPENDIX B

Truck Crash Causation and Compliance

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1: PROJECT INTRODUCTION AND OVERVIEW

Prior to the early 2000s, there existed a serious dearth of scholarly knowledge about truck crash causation. What research did exist primarily focused on driver safety issues, a subject of considerable political contention in the wake of the 1980 deregulation of the trucking industry (Krass 1993), and again in the 1990s as the Department of Transportation weighed changes in commercial driver work rules (Mitler 1997). The Motor Carrier Safety Improvement Act of 1999 mandated a study of commercial vehicle crash causation. In response to this mandate, the Federal Motor Carrier Safety Administration (FMCSA) and the National Highway Transportation Safety Administration (NHTSA) jointly launched the Large Truck Crash Causation Study (LTCCS), a research effort that successfully obtained comprehensive data on the characteristics and causes of truck crashes in the United States between 2001 and 2003. Much of the literature surveyed here comes out of these efforts.

2: METHODOLOGY

The authors located publications used in this review by means of electronic keyword searches in the Transportation Research Board's TRIS Online database; the Harmer E. Davis Transportation Library of the University of California's Institute of Transportation Studies; the University of California's Melville electronic archive; and the increasingly indispensable Google Scholar. The authors also examined publications referenced in those located via the keyword search.

Where possible, the authors limited the scope of their search to publications from 1996 and later. For publications that are part of a regular series, such as FMCSA's *Large Truck Crash Facts,* the authors used the most recent edition.

3: GENERAL TRENDS IN TRUCK ACCIDENTS

A significant problem surrounds any study of vehicle accidents, even those involving commercial vehicles: in California and many other states, localities are not required to report accidents to the Highway Patrol (or its equivalent agency in other states) if no injuries or fatalities result from the accident. As a result, only the data sets for fatal and injury accidents are sufficiently robust for detailed statistical analysis. The LTCCS accordingly considered only fatal and injury accidents in its analysis.

The combination of deregulation and "pull-oriented" logistics practices (such as "just-in-time" manufacturing) has caused trucking to become ever more important to the US economy. This is reflected in a 51% increase in large (>10,000 lb gross vehicular weight) truck registrations and an 84% increase in vehicle-miles traveled (VMT) by large trucks between 1984 and 2004 (FMCSA 2006). However, trucking has become safer, with 5% fewer trucks involved in fatal accidents over this period; a truck is now 49% less likely to be involved in a fatal crash per VMT. By comparison, passenger vehicles are only 43% less likely to be involved in a fatal crash per VMT. Since 1994, 10% fewer trucks have had a property-damage-only crash and property-damage-only truck crashes are now 32% less likely to occur per mile traveled. (21% fewer property-damage-only passenger vehicle crashes occurred per mile in 2004 than in 1994.) Alcohol is now far less likely to play a role in truck crashes: truckers involved in crashes were 77% less likely to have blood alcohol concentrations over 0.01 grams/deciliter in 2004 than in 1994 (LTCCS 2005).

Combination trucks are generally more likely to be involved in fatal crashes than single-unit trucks or passenger vehicles. While combination trucks were 55% less likely to be involved in a fatal crash in 2004 compared with 1984 (compared with only a 33% reduction for single-unit trucks and a 43% reduction for passenger vehicles), a combination truck is still 53% more likely than a single-unit truck and 81% more likely than a passenger vehicle to have a fatal crash (LTCCS 2005).

On an annual basis, the number of fatal truck accidents varied between roughly 4000 and 6000 for fifteen years after 1975 (the first year for which comprehensive data are available) before settling into the 4000-5000 band around 1990. During this time, the raw numbers of registered trucks and total truck VMT have each skyrocketed, as mentioned previously. This has led to sharp declines in fatal truck-involved accidents per 100 million VMT (from 5.5 in 1980 to roughly 2.5 by 2000) and per 100,000 registered trucks (from ~105 in 1979 to ~60 in 2000). Trucks are still more likely than passenger cars to become involved in a fatal accident on per-mile and per-vehicle bases: since 1990, the likelihood of a fatal accident has varied between 20% and 40% greater per mile for trucks, and an individual truck has been 2.6-3.0 times as likely to have a fatal accident over the same interval. Since 1975, the percentage of all fatal crashes that has involved a large truck has risen from 10% to over 13%, perhaps reflecting safety improvements (airbags, crumple zones, etc.) that have made car-on-car crashes considerably less dangerous over the same period (Moonesinghe *et al* 2003).

California is one of the most dangerous states for truck crashes, ranking fourth (behind Delaware, Florida, and Maryland) in terms of the number of fatal truck crashes per mile of public road. For every 1000 miles of public road, California had 2.1 fatal truck crashes per year between 1996 and 2000 (Moonesinghe *et al* 2003).

4: GENERAL CHARACTERISTICS OF TRUCK CRASHES

Golob and Regan (2004) find that the peak periods for truck accidents are on weekdays 9AM-2PM, 3-7AM, and 12-3AM. Reflecting the commercial nature of truck traffic, only 17% of total combination truck crash-caused fatalities (both vehicle occupants and non-occupants) occur on Saturday and Sunday; this figure is even lower for single-unit trucks, totaling 12% of fatalities. 64% of occupant and 53% of non-occupant fatalities in combination truck crashes take place during the day (dawn to dusk); these figures are 82% and 74%, respectively, for single-unit trucks (Moonesinghe *et al* 2003).

The overwhelming majorities of both combination and single-unit truck fatalities occur in rural areas—71 and 60 percent, respectively. This reflects the prevalence of two-lane undivided roads in rural areas; the higher speed of rural traffic; and the scarcity of emergency medical care in non-urbanized areas. The dearth of pedestrians and bicyclists on rural roads means that only 45 and 26 percent of non-occupant fatalities caused by combination and single-unit crashes occur in rural areas, respectively (Moonesinghe *et al* 2003).

Moonesinghe *et al* note, "More large truck crash fatalities occur in the first hour after a break of at least eight hours than during any other hour. In general, as the number of hours increase, after the required break of at least eight hours, there are fewer fatal crashes." While this seemingly counterintuitive fact seems to negate the safety justification for hours-of-service limits, it may simply be a result of the relative infrequency of drivers operating for more than twelve hours at a stretch. For crashes involving single-unit trucks in which the truck's trip length is known, the vast majority of fatalities (71%) occur when the truck's one-way trip distance is 50 or fewer miles, again reflecting the local nature of single-unit truck traffic. By contrast, for crashes involving combination trucks with known trip lengths, fatalities are relatively evenly distributed across trips of all distances (<50, 51-100, 101-200, 201-500, and >500 miles), with no trip length accounting for less than 14 or more than 26 percent of fatalities (Moonesinghe *et al* 2003).

While the majority (62%) of fatal crashes not involving a truck consists of a single car crashing, only 18% of fatal truck-involved accidents result from a single truck crashing. This reflects both the low likelihood that trucks will have a single-vehicle accident (a result of better foul-weather driving ability and considerably lower alcohol usage on the part truck drivers, relative to passenger car drivers) and the greater safety that a truck provides its occupants relative to a passenger car. A substantial majority of fatalities (63%) caused by truck crashes results from a combination truck crashing into another vehicle. The next-largest portion of fatalities (20%) occurs as a result of a single-unit truck crashing into another vehicle (Moonesinghe *et al* 2003).

For both single-unit and combination trucks, rollovers are the leading cause of death in single-vehicle truck crashes. 64% of such fatalities occurred in crashes where a rollover occurred. By comparison, only 9% of fatalities in multiple-vehicle crashes involving trucks occurred in incidents involving truck rollover. As expected, total vehicle weight and rollover show high positive correlation for single-unit trucks: trucks that roll over in single-vehicle and multiple-vehicle crashes are 23 and 19 percent heavier on average, respectively, than those that do not. For combination trucks, the relationship is also quite strong, at least for trucks pulling only one trailer: trucks that roll over in single-vehicle and multiple-vehicle crashes pull trailers 52 and 33 percent heavier, respectively, than those that do not (Moonesinghe *et al* 2003).

Crashes involving a jackknife account for a surprisingly small portion (10%) of fatalities occurring as a result of combination truck crashes. As an outsider might suspect, propensity to jackknife is a negative function of trailer weight for combination trucks. Interestingly, trailer weight tends to impact the likelihood of jackknife only in multiple-vehicle crashes: while mean trailer weight for one-trailer combination trucks is actually slightly higher (by less than one percent) for trucks that jackknife than those that do not, one-trailer combination trucks that do not jackknife pull trailers that are on average 32% heavier than one-trailer trucks that jackknife (Moonesinghe *et al* 2003).

5: CAUSAL FACTORS IN TRUCK CRASHES

5.1 Roadway and Traffic Characteristics

Two-lane, undivided roads account for 51% of all fatalities caused by large truck crashes. Interestingly, 59% of non-occupant (cyclist/pedestrian) fatalities caused by combination truck crashes occur on divided highways of two or more lanes; by contrast, only 35% of non-occupant fatalities caused by single-unit truck crashes occurred on such roads. The vast majorities of fatalities caused by both combination and single-unit truck crashes—73 and 67 percent for occupants, and 78 and 70 percent for non-occupants—occur on portions of road away from traffic control devices such as traffic lights, stop and yield signs, and crossing guards. Again reflecting the urban nature of single-unit truck traffic, single-unit truck fatalities are more likely to occur at junctions (driveways, intersections, ramps, etc.) than combination truck fatalities—41 versus 35 percent, respectively (Moonesinghe *et al* 2003).

Golob and Regan (2004) use logit models to describe the probabilities of large truck crashes of various types on the freeways of Orange County, California, using data from Caltrans' Traffic Accident Surveillance and Analysis System on average annual daily traffic (AADT), both total and truck-only, and police-reported crashes.[1] They find that the likelihood of a truck being involved in a crash is an increasing function of the percentage of traffic due to trucks; additionally, for a given proportion of traffic due to trucks, the probability of a truck-involved crash increases with the prevalence of trucks with 5+ axles. However, when the proportion of traffic consisting of trucks is held constant, truck accidents actually fall as total AADT increases. With constant proportions of trucks on the road, accidents are most likely to occur on weekdays; between 9 AM and 2 PM, 3 AM-7 AM, and midnight-3 AM; and on dry, rather, than wet, roads. (Concerning the latter, Golob and Regan surmise that professional truck drivers are better able to handle rain-soaked roads than the average motorist.) Truck crashes tend to involve a lane change or merge: fully 42.5% of truck-involved crashes involve a lane change/merge, compared to 17% of those not involving a truck. 43% of lane change/merge crashes involving trucks occurred when the truck was changing lanes, with 52% occurring while the other vehicle was changing lanes and 5% when both vehicles were doing so.

5.2 Driver Factors

Passenger car drivers bear much more of the blame in passenger-car-on-commercial-vehicle collisions. In the classic sideswipe opposite direction crash in which one vehicle encroaches into the other's lane, encroachment by the passenger car into the truck's lane resulted in ten times as many fatalities as encroachment by trucks into the passenger car's

[1] CHP reports all freeway accidents to which its officers are summoned, and not just those causing injuries and/or fatalities.

lane (Moonesinghe *et al* 2003). Drivers of commercial vehicles are generally less likely than passenger vehicle drivers to make driving performance mistakes or to suffer from intoxication, fatigue, and illness. The one exception to this rule is speeding: commercial drivers are more likely than passenger car drivers to travel above the maximum speed permissible for their vehicle classification (LTCCS 2005).

Monaco and Williams (2000) develop a probit model to determine likelihood of being involved in an accident (as well as receiving a moving or logbook violation), using explanatory factors such as pay characteristics, education levels, demographic factors, owner-operator/employee status, trailer type, firm size, and source of driver training. They find that compensation by hour and/or mileage significantly reduces the likelihood of accident involvement relative to payment as a percentage of the load value. Other factors that significantly decrease the likelihood of an accident include: working for a firm with between 1000 and 4999 employees; and being separated/divorced/widowed, which presumably reduces the incentive to rush one's load. (Note, however, that this does not have a statistically significant impact on moving violations.) Meanwhile, receiving training from the trucking company—as opposed to a private or public trucking school, the military, or some other source—significantly increases the likelihood of an accident. In general, compensation practices and training levels are more significant determinants of safety than demographic indicators.

As mentioned above, the compensation paid to drivers exercises a significant impact on safety. Krass (1993) finds a clear, significant inverse relationship between crash risk and wages during the period following the 1980 deregulation of interstate trucking. Using longitudinal data on compensation and performance collected by J.B. Hunt on 11,540 of its unscheduled over-the-road drivers, Rodriguez *et al* (2003) develop a set of count models to determine the impact of wages paid to an individual driver on the number of crashes in which he will be involved in the future. They find that for every increase in pay rate of one standard deviation, the expected number of crashes falls by 40 percent. While the causal relationship is unclear, the busiest drivers tend to be the safest: for every increase of the number of dispatches over the mean for the length of the study, the expected crash count falls by 36 percent.

The financial state of a motor carrier also has a considerable impact on its safety performance. Firms in difficult financial situations, with little cash on hand, tend to force their drivers into unsafe work situations; have considerable incentive to cut corners on maintenance; and use older, less safe equipment in the first place. They may also employ less risk-averse drivers. Rodriguez *et al* (2004) find that among small trucking firms (<100 trucks), crash frequency increased as liquidity and labor expenses as a percentage of revenue fell. They find further that expenditures on safety, vacation, and health benefits also manifest themselves in fewer crashes; surprisingly, direct compensation does not have a statistically significant impact on safety.

5.3 Rollover and Jackknife

Moonesinghe *et al* (2003) develop simple logit models to determine the likelihood of rollover and jackknife based on truck dimensions and weight, posted speed limit, weather and visibility conditions, and curvature of the road. Unsurprisingly, all of these factors had highly statistically significant (*p*-values below 0.01) impacts on jackknife and rollover propensity. A 10 mph increase in the posted speed limit resulted in 172 and 49 percent increases in the likelihood of rollover for single-unit and combination trucks respectively, while a 10% increase in cargo weight resulted in 10 and 23 percent respectively greater likelihood of rollover. An increase of 10 percent in total truck weight resulted in a 2 percent decline in the likelihood of a jackknife. Jackknife is highly positively correlated with truck length, with a 10 percent increase in total truck length resulting in a 14 percent increase in the likelihood of jackknife. However, length reduces propensity to roll over: for every 10 percent increase in overall length, the likelihood of rollover falls by 10 percent for single-unit trucks and 21 percent for combination trucks (Moonesinghe *et al* 2003).

6: THE ROLE OF NON-COMPLIANCE IN TRUCK CRASHES

As mentioned previously, much of the research in the area of truck crash causation focuses on the role of drivers. Such an emphasis makes sense: among the 44% of large truck/passenger car crashes in which investigators assigned blame ("the critical reason," in LTCCS parlance) to the truck, driver error was the primary factor in 88% of incidents, with faulty equipment accounting for only 10% and roadway conditions the remainder (LTCCS 2005). However, as Blower and Campbell (2002) note, few—if any—traffic accidents have a single causal factor, the absence of which would have prevented a collision altogether. Poor road conditions, driver error, and mechanical defects can occur simultaneously. While 55% of trucks involved in fatal crashes display at least one mechanical defect, with half of these of a nature that would result in the vehicle's removal from service at a roadside inspection station (Blower 2002), such defects may not occur appreciably more often in trucks that do crash than in the general truck population as a whole: out-of-service (OOS) orders were issued in 23% of the more than 2 million roadside vehicle inspections performed in 2004. By comparison, only 6.5% of driver inspections and 5.6% of hazardous material inspections resulted in an OOS order (Cambridge/Maineway 2006).

Murray *et al* (2005) find that, over their study interval, drivers cited for size/weight violations were 21% more likely to have a crash than those not so cited. Other compliance-related citations associated with increasing likelihood of crashes include medical certificate violations (18% more likely), falsified/missing logbook (56%), excessive hours of service (41%), and disqualified driver (51%).

LTCCS (2005) estimated that, of the trucks that crashed during the study period, 29.4% had vehicle issues of some sort—brake failure being the most common. Relatively small numbers of trucks involved with crashes had cargo shift/attachment issues (4.0%/3.0%), drivers pressured to operate despite fatigue (3.2%) or illness (2.8%), or drivers using illegal drugs (2.3%) or alcohol (0.8%).

In crashes between a passenger car and a large truck, the passenger vehicle was assigned blame (the critical reason) in 56 percent of crashes. For both passenger cars and large trucks, driver error of some sort accounted for the overwhelming majority of causal factors deemed the "critical reason"—88.7 and 87.7 percent, respectively. Vehicle defects of some sort accounted for nearly twice as many critical reasons for large trucks as for passenger vehicles—8.0 vs. 4.1 percent, respectively (LTCCS 2005).

7: SAFETY-RELATED ENFORCEMENT

Using FMCSA data, Cambridge/Maineway (2006) determine that 3,014,907 roadside inspections occurred in 2004. Driver, vehicle, and hazardous materials inspections took place during 98, 75, and 6 percent of these. 73% of these inspections identified a violation, and 27% resulted in an OOS order. Vehicle violations were found in 69% of vehicle inspections, and 23% of vehicle inspections resulted in removal from service. Driver and hazardous material violations and removal from service occurred considerably less frequently: 36% of driver inspections found a violation, with 6.5% resulting in an OOS order, while 18.6% of hazmat inspections discovered violations and 5.6% resulted in removal from service.

There is a distinct dearth of California-specific literature concerning commercial vehicle compliance and safety issues. However, in articles concerning operational difficulties at ports of entry along the US-Mexican border (Ojah *et al* 2002) and the drayage sector surrounding the ports of Los Angeles and Long Beach (Monaco/Grobar 2004), the authors located information relevant to large truck compliance/safety in California.

Ojah *et al* (2002) examine the problem of inefficient inspection procedures at the 25 ports of entry along the US-Mexico border. The vast majority of cross-border truck traffic occurs at only a few of these: San Ysidro/Otay Mesa/Tijuana and Calexico/Mexicali in California; Nogales in Arizona; and El Paso/Ciudad Juárez and Laredo/Nuevo Laredo in Texas. As a result of a doubling in northbound truck crossings between the 1994 implementation of the North American Free Trade Agreement and today, most of these crossings have become badly congested, particularly San Ysidro/Tijuana and Laredo/Nuevo Laredo. While much of their article concerns management practices outside the purview of this paper, Ojah *et al* identify a number of initiatives that could improve the efficiency of vehicle inspections, a particularly important goal given the longstanding outcry over allowing Mexican trucks on American roads (GAO 1996). These include expansion of pre-clearance programs; weigh-in-motion scales, transponders, and other intelligent transportation systems (ITS) technologies; and performing state DOT vehicle safety inspections on trucks waiting in line for Department of Homeland Security inspections.

Monaco and Grobar (2004) survey one of the most important sub-sectors in California trucking: drayage between the ports of Los Angeles and Long Beach and the logistics districts near downtown Los Angeles and in western San Bernardino and Riverside Counties. While much of their paper concerns the demographic makeup of drivers, the prevalence of owner-operators, and the time drivers spend waiting in line for loads, Monaco and Grobar devote a section to the issue of safety in the chasses on which containers rest while being towed by trucks. In California, responsibility for an unsafe chassis falls to its owner—usually one of the shipping companies, such as Maersk-Sealand or P&O Nedlloyd—but drivers still face considerable incentive to take unsafe chasses on the road: 22% of drivers surveyed reported that the last time they were offered an unsafe chassis, they took it on the road anyway. Monaco and Grobar develop a logit model to determine the likelihood of taking an unsafe chassis on the road. They find that race, ethnicity, experience, tenure, and pay do not have a significant impact on the probability of pulling an unsafe chassis, but working for a medium-small firm (100-249 drivers) increases the likelihood of taking an unsafe chassis on the road relative to working at a firm with fewer than 100 drivers.

8: DISCUSSION

In light of the facts encountered during this review, the usefulness of weighing and compliance stations should be apparent. That the percentage of truck accidents caused by defective equipment is nearly twice that for car-only accidents (LTCCS 2005) indicates the importance of finding non-compliant trucks and taking them off the road as quickly as possible. In particular, increasing inspectors' ability to find trucks with defective brakes can save lives and money, since bad brakes by far outweigh any other vehicle-related defect in terms of relative importance to truck safety (LTCCS 2005). The significant impact of excessive weight on the likelihood of rollover (Moonesinghe *et al* 2003) also makes a case for faster and more efficient weighing practices.

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APPENDIX C

Security-Related Aspects of Commercial Vehicle Operations: Review of the Literature

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EXECUTIVE SUMMARY

This report constitutes an interim deliverable for PATH Project Task Order 6105 under contract 65A0208 ─ "Virtual Weigh & Compliance Station Test Bed". It was prepared as an internal draft document of a review of the literature for security-related aspects of commercial vehicle operations, especially in the context of terrorism since the events of September 11, 2001. Prior to this date, 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 September 11, 2001, 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. To assess the risk and vulnerabilities to threats, the trucking industry can perform in-house security audits and evaluations

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. Post-September 11, 2001 security-related programs cover a broad range of areas, as follows: 1) procedural changes, 2) employment-related practices, 3) employee training procedures, 4) physical security measures, 5) implementation of technology measures, 6) communication procedures, 7) information sharing initiatives, 8) pre-screening and pre-processing systems, 9) security assessments, 10) education and outreach efforts, and legislation.

Specific examples of security-related programs include 1) security coordination with vendors, 2) re-evaluation of cargo-related security, 3) improved preparedness, 4) not listing products by name on bills of lading or on invoices given to the driver, 5) enhanced scrutiny and background checks for existing and new employees, 6) the issuance of identification badges, and stricter discharge clauses, background checks, 7) FMCSA conducting onsite visits to motor carriers that transport hazardous materials through its *Security Sensitivity Visits Program*, 8) implementing the Transportation Worker Identification Card that provides a uniform and nationwide standard for secure identification of trucking industry workers, 9) instructing drivers not to stop and/or render assistance except in the case of clear and obvious emergency situation, 10) alerting drivers to potentially deceptive tactics used in truck hijackings, 11) emphasizing to all trucking company employees, not only drivers, to stay alert and remain aware of their surroundings at all times, especially when transporting hazardous materials, 12) advising truck drivers to notify their supervisors of suspicious shipments or to contact law enforcement to request inspection of shipments, 13) re-assessing specific routes and advising drivers transporting particular hazardous materials to avoid highly populated areas and use alternate routes if feasible to avoid such areas, 14) instructing drivers to verify seal integrity at each stop, 15) technology measures include systems for vehicle monitoring and inspection, cargo detection and tracking, access control, and communications.

A common thread running through most if not all of these security-related measures and programs is the recognition of how crucially important it is to form multi-organizational

alliances, coalitions, and partnerships to enhanced the chances of success for such implemented initiatives. The exact nature of the alliances and partnerships depend on the initiative's objective, which helps determine whether multiple countries or the public and private sectors, or government and business, or members of the trucking industry or some combination of these stakeholders work together.

With the implementation of many security-related initiatives and programs, there have been accomplishments that basically serve as initial-stage successes. Nevertheless, the literature contains gaps in documenting more quantitative assessments of the extent of the terrorist threat to the trucking industry and the effectiveness of implemented security-related measures. More careful quantitative investigations in this area are needed.

1: INTRODUCTION

The issue of homeland security directly linked with U.S. port security and commercial vehicle operations is currently very much in the news. This is likely due to a combination of factors including 1) the nation having just observed the fifth anniversary of the September 11, 2001 terrorist attacks, 2) the upcoming midterm congressional elections and the jockeying among members of Congress for who can be identified as toughest on security, and 3) the controversy earlier this year over the proposed purchase by a Dubai-owned company of terminal operations at six major U.S. seaports. The Senate is expected to vote any day now on its version of a measure already passed by the House in May that, in brief, would impose deadlines on background checks for port workers, expand a program to screen for "dirty bombs" and authorize $400 million to help ports bolster anti-terrorism defenses at ports, including the Los Angeles-Long Beach port complex (1).

Whatever the motivation, put quite simply, the monitoring of commercial vehicle operations in whatever environment they operate ─ at national borders, ports, or on the road ─ is significant because it can be a matter of life and death. Obviously, it has taken on added importance in the United States since the terrorist acts of September 11, 2001 and this date will be remembered as a major turning point and major shift in priorities for the nation. Between 1983 and just prior to the September 11 attacks, the U.S. experienced terrorism both abroad and on U.S. soil ─ literally at the World Trade Center in New York City in 1993 ─ and though security relative to commercial vehicle operations played an important role during this time, its focus was less on the terrorism threat and more on vandalism and the theft of trucks and/or its cargo, as well as interdicting the transport of illicit cargo including people (illegal/undocumented immigrants) and contraband such as illicit drugs (2, 3, 4). In general, before September 11, 2001 trucks were not a typical target or means for terrorism. According to (5), "throughout the world, there are probably fewer than a dozen documented cases of Class 8-sized trucks being used in terrorist attacks. Other priorities before September 11, 2001, especially of federal and state agencies at the nation's ports of entry, include commercial cargo processing and commercial vehicle and driver safety. Moreover, even prior to September 11, 2001, the use of technology also played a sizable role.

After September 11, 2001, 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. Ancillary though related security threats involving commercial vehicles also include the transport of illicit cargo and use of criminal means in support of terrorist groups. Thus while the successful smuggling of the aforementioned contraband would certainly result in undesirable outcomes, they clearly would not approach in magnitude the potential impacts of the use of weapons of mass destruction like nuclear weapon detonation, biological agent dispersal, or chemical attack utilizing cargo containers or trucks.

The objective of this report is to document our review of the literature in the area of commercial vehicle operations vis-à-vis the security issue. Moreover, in the wake of the September 11, 2001 terrorist attacks, we have decided to focus this literature review on the post-9/11 environment and the long-term, if not permanent, changes it has produced in the operation of commercial vehicles.

It must be noted, though, that the 1993 World Trade Center bombing in New York City and the 1995 bombing of the Federal Building in Oklahoma City, which were carried out with commercial vehicles, involved leased trucks with legally obtained cargo such as diesel and gasoline fuels and fertilizers. Thus, even if the commercial trucking industry were secure and inaccessible to terrorists, then the "means and opportunity for executing a terrorist act involving trucks would not be eliminated and perhaps not even reduced" (5). Trucks are legally and easily accessible through truck rental agencies, leasing organizations, truck dealerships, private sellers, importers, and theft rings. Moreover, obtaining trucks and cargo illegitimately puts potential terrorists at risk of prematurely exposing their plans and associates. There are thus continuing gaps and vulnerabilities that allow the use of trucks in the execution of terrorist acts that need to be addressed.

The remainder of this report is organized by first discussing who the major organizational players are at both the federal and state level in California in Section 2 followed by possible security threats to the trucking industry in Section 3; In Section 4, we present the risk and vulnerabilities posed by these threats to the trucking industry; In Section 5, we discuss the many security-related measures and programs that have been put in place since September 11, 2001, while in Section 6 we examine what the gaps are in the literature. Finally, we offer conclusions in Section 7.

2: FEDERAL AND CALIFORNIA AGENCY FREIGHT SECURITY STAKEHOLDERS: WHO ARE THE MAJOR PLAYERS?

There are many local, state, and federal agencies that play various important roles in establishing and maintaining the security of truck cargo movements in different environments: international border crossings, sea and air ports, and on the road. Moreover, international shipments arriving at one of the U.S.'s international gateways frequently fall under the jurisdiction of *multiple* federal, state, and local agencies, which makes coordination and cooperation and the formation of alliances and partnerships among such agencies essential for the success of security-related measures and for benefits to be realized. For example, international shipments arriving at the Port of Los Angeles-Long Beach seaport complex are governed by the security regulations of the Department of Homeland Security, the Department of Agriculture, California and the LA-LB Port authorities, and California, and Los Angeles and Long Beach police. Similarly, truck shipments moving through the US/Mexican border crossing at Otay Mesa fall under the jurisdictions of Mexican and US Customs, the FMCSA and California's counterpart agency for motor carriers, and local and state police. The formation of multi-agency alliances and partnerships ─ sometimes cross-border ─ contributes to the overall success of security-related enterprises. We will discuss more of these partnership aspects in Section 4 of this report. Tables 1 and 2 describe the federal and state/local agencies, respectively, involved with security of freight movements (6).

TABLE 1 Federal Agencies and Their Roles in Goods Movement Security

Federal Agency	Role
Immigration and Customs Enforcement	Responsible for protecting US borders, conducting surveillance, detecting and interdicting suspected smugglers; conducting immigration inspections on travelers seeking entry to US at ports of entry; identifying and removing people who have no lawful immigration status
Border Patrol	Responsible for maintaining control at US borders
Coast Guard	Responsible for enforcing immigration and customs laws at sea and for protecting US's maritime borders
Transportation Security Administration	Responsible for security in all transportation modes, developing policies, strategies, and plans for dealing with threats to transportation security and ensuring the adequacy of security measures for transportation of people and goods.
Critical Infrastructure Assurance Office	Responsible for assessing the risk exposure and dependencies on critical infrastructure, including transportation infrastructure
FBI National Domestic Preparedness Office	Responsible for providing training, funds for the purchase of equipment, support for the planning and execution of exercises, technical assistance for states and local jurisdictions to prevent, plan for, and respond to terrorism acts.
Federal Emergency Management Agency	Responsible for reducing loss of life and property and protecting nation's critical infrastructure from all types of events including terrorism
FBI National Infrastructure Protection Center	Government/Private sector partnership with responsibilities related to computer intrusions and infrastructure issues
National Bio-Weapons Defense Analysis Center	Responsible for developing countermeasures to potential terrorist attacks using WMD

Source: I-95 Corridor Coalition, "Container and Truck Trailer Security Project Final Report", April 2004.

TABLE 2 California and Its Local Agencies and Their Roles in Goods Movement Security

California / Local Agency	Role
Highway Patrol and local law enforcement agencies	"First responders" to security-related incidents occurring on transportation systems
California Truck Safety Enforcement	Responsible for conducting motor carrier safety compliance inspections
Port Authorities	Responsible for physical security of port and terminal complexes
California Public Safety	Responsible for administering enforcement, education, and prevention initiatives
California Emergency Management	Responsible for assisting in preparing for and coping with events such as terrorist acts; coordinating federal, local, and private resources statewide during disasters and emergencies, e.g., terrorist act
California Homeland Security	Responsible for planning, coordination, and implementation of all homeland security prevention, protection, and response operations at statewide level
Caltrans	Responsible for operating and maintaining transportation infrastructure and identifying critical transportation infrastructure
Metropolitan Planning Organizations	Responsible for planning and programming improvements to local transportation systems and, in partnership with Caltrans, identify critical transportation infrastructure

Source: I-95 Corridor Coalition, "Container and Truck Trailer Security Project Final Report", April 2004.

3: ASSESSMENT OF THE KEY THREATS TO THE TRUCKING INDUSTRY

A *threat assessment* defines and characterizes the terrorist threat posed to an organization. This section focuses on the key security-related threats to the trucking industry in light of the events of September 11, 2001. The primary threat from the use of trucks involves using stolen trucks as instruments in carrying out terrorist acts, in other words, as part of the weapon itself. In words used by the Department of Homeland Security (DHS) and the Federal Bureau of Investigation (FBI), trucks or other heavy transport vehicles may be used as "vehicle-borne improvised explosive devices (VBIED)" (7). The use of trucking industry assets to commit terrorism continues to be a threat as well as a perceived threat because

- Terrorists have repeatedly used heavy vehicles to conduct VBIED attacks in other countries as well as in the United States.
- The U.S. airline industry has significantly increased its security procedures and thus its vulnerability has decreased over the past five years resulting in terrorist planners looking for more vulnerable or softer targets.
- There are a large number of trucks carrying large quantities of hazardous materials and military cargo and relatively high frequency of major security breaches that occur in the commercial trucking industry.
- Terrorist planners have considered how heavy vehicle drivers acquire training and Commercial Driver's Licenses (CDLs) with permission to carry hazardous materials (HAZMAT).
- Terrorists have shown interest in planning attacks employing hazardous materials, which trucks regularly carry.

There is also a security concern that the cargo, including HAZMAT, explosives, weapons, as well as non-hazardous materials could be used for a terrorist attack. For non-hazardous materials it may be less obvious why such cargo would be stolen with the intent to carry out terrorist actions. For example, food and water could be stolen with the purpose of poisoning the food or water supply. Another scenario deals with the theft of seemingly innocuous cargo such as uniforms for airline employees, e.g., maintenance workers, to make it easier for potential terrorists to infiltrate sensitive areas of the airport to get access to airplanes.

In 2003, an investigation into security measures in the commercial trucking industry, sponsored by the Federal Motor Carrier Safety Administration (FMCSA), was conducted by means of a survey of 52 trucking companies. Twenty responses were received for a 38.5% response rate and respondents reported the following functionality associated with their trucking businesses: general freight, HAZMAT, food and alcohol, military freight, and dry bulk tank carriers. The trucking companies were not randomly selected but were biased toward large companies. In terms of threats to security, the survey asked the question: *What do you perceive to be the key national security (terrorism-related security) threats to your commercial trucking operations?* Survey responses are shown in Table 3 (5).

TABLE 3 Perceived Threats to Trucking Operations

Perceived Threats to Trucking Operations	Number of Respondents	Percentage of Total
Stealing vehicles to be used as instruments of terrorism	7	35%
Introduction of narcotics, WMD, contamination of food/water supply; miss-delivery of dangerous goods aimed at a disastrous result; truck entry to a consignor/consignee facility with intent to do harm	6	30%
Hijacking of trucks and drivers	5	25%
Theft of cargo and equipment, so-called "economic terrorism"	5	25%
Harm to employees, drivers' security traveling over roadways	5	25%
Theft of conventional arms, ammunition, and explosives	4	20%
Vandalism	4	20%
Disruption of services and roadways	2	10%
Not knowing the client and cargo shipped	2	10%
Organized crime and local gang elements	2	10%
Theft of nuclear weapons materials	1	5%
None	2	10%

Source: Transportation Research Board, "Security Measures in the Commercial Trucking and Bus Industries Synthesis 2", Federal Motor Carrier Safety Administration, 2003.

Note that the total percentages exceed 100% because respondents were allowed to select all perceived threats that applied to their specific circumstances and setting.

In 2004, the American Transportation Research Institute (ATRI) conducted a survey of over 10,000 agricultural and food transport carriers as part its research into food transport security issues and practices[1]. This work was sponsored by the U.S. Department of Agriculture and the Food and Drug Administration. Survey responses to questions dealing with security concerns and overall threats are summarized in Table 4 (8).

[1] No detailed information on survey methodology including response rate was available from this source

TABLE 4 Agricultural/Food Truck Transport Security Concerns

Agricultural/Food Truck Transport Security Concerns	Percentage of Total
Cost of government mandated security measures	8.6%
Parking security	12.8%
Theft of equipment or truck	16.2%
Driver fraud	18.6%
Tampering with vehicle	20.6%
Truck being used as a weapon	21.6%
Employee security	24.7%
No new security concerns	25.8%
Hijacking	27.0%
Cargo contamination	27.4%
Compliance issues	30.1%

Source: Intelligent Transportation Systems Institute, Center for Transportation Studies, University of Minnesota, and American Transportation Research Institute, "Homeland Security and the Trucking Industry", 2005.

Note that the total percentages exceed 100% because respondents were allowed to select all perceived threats that applied to their specific circumstances and setting.

Survey responses were somewhat mixed regarding the types of security concerns. Some of the above-listed security concerns are definitely threats from a terrorism perspective such as "Cargo contamination", "Truck being used as a weapon", which were noted by 27.4% and 21.6% of the respondents, respectively. However, slightly more than one-quarter of the respondents felt that there were no new security concerns dealing with truck transport of food and other agricultural products and nearly one-third of respondents indicated that complying with security measures were of concern.

The literature, unfortunately, does not contain any further quantitative assessment of the threats to the trucking industry. For example, regarding theft of cargo, there is no centralized reporting mechanism to document this in terms of total theft volume and distribution of thefts by type of cargo (5). So attempts at estimating such theft statistics need to use alternative means such as obtaining information directly from a representative sample of trucking companies or by indirect means and the former may be difficult due to security concerns and confidential company information. Similar difficulties would likely be encountered if attempting to document the volume and distribution of driver fraud cases or vehicle tampering.

The FBI estimates that in the range of $12 billion to $20 billion is lost annually in truck cargo thefts, which is less than one-half of a one percent of the Bureau of Census estimate of approximately $4.9 trillion in annual U.S. truck cargo. The American Trucking Association believes that even the higher FBI estimate is a substantial underestimate by a factor of possibly 10 to 20 (5).

4: ASSESSMENT OF THE RISK EXPOSURE AND VULNERABILITY TO THE TRUCKING INDUSTRY

There are several methods that may be used to understand the risk posed to the trucking industry by the threats discussed the Section 2 including *vulnerability assessment* and *risk assessment tools*. These methods determine how susceptible an organization is to the threat and the points of vulnerability and risk. This section focuses on the key security-related risk assessment methods used by the trucking industry in light of the events of September 11, 2001 (9).

Trucking companies can assess their vulnerabilities and risks to threats by conducting in-house security audits and evaluations. Terminals may be audited for security risk exposure and accessibility. Reviews can be performed by operator, facility, and customer. On-the-road security assessments can also be conducted.

In summary, the trucking industry generally employs threat assessments by individual location. Other factors that are occasionally considered include the product, the customer, a crime index, reports, and claims history and insurance statistics. These assessments are geared more toward cargo theft than acts of terrorism.

The ATRI survey of agriculture/food truck transport carriers inquired participants about the risk exposure and vulnerability of industry concerns some of which may be considered security threats. Survey responses are summarized in Table 5 (8).

TABLE 5 Risk Exposure and Vulnerability to Agricultural/Food Truck Transport Industry Concerns

Trucking Industry Concerns	Probability of Risk Exposure/Vulnerability				
	Low	Low-Med	Med	Med-High	High
Rest stop/parking	24%	20%	27%	20%	9%
Chemical/fertilizer	42%	18%	19%	15%	6%
Truck used as WMD	42%	21%	19%	13%	5%
Cargo-based	36%	26%	24%	10%	3%
Equipment/Truck-based	36%	27%	25%	9%	3%
Deliberate contamination	47%	20%	18%	10%	5%
Accidental contamination	57%	23%	14%	4%	2%
Personnel-based	43%	27%	20%	7%	3%

Source: Intelligent Transportation Systems Institute, Center for Transportation Studies, University of Minnesota, and American Transportation Research Institute, "Homeland Security and the Trucking Industry", 2005.

Most of the industry concerns listed in Table 5 may be considered threats to security in the context of terrorism.[2] Based on survey responses, we make the following observations:

- At most 6% of responses thought that their truck carrier had a high risk exposure to particular terrorism-related security threats. Likewise, at least 36% of responses thought that their truck carrier had a low risk exposure to these same terrorism-related security threats.
- For arguably the most serious terrorism-related security threat ─ "Truck used as WMD" ─ more than 4 of every 10 responses felt the risk exposure to this threat was low, nearly 2/3 of responses felt the risk exposure was either low to low-med, and only 5% felt there was a high risk to this threat.

While these responses are valuable and informative, and are assumed to be well thought-out responses of people in the trucking industry, they are opinions and not necessarily based on quantitatively-based analyses of risk exposure or vulnerability assessments for the specific security concerns.

5: SECURITY-RELATED MEASURES, PROCEDURES, AND PROGRAMS

Before the events of September 11, 2001, the trucking industry generally did not design its security measures to protect against acts of terrorism. However, because the trucking industry regularly shipped hazardous materials and was nonetheless concerned about cargo theft, many pre-September 11, 2001 security measures were similar in function to anti-terrorist measures put into place after September 11, 2001.

Prior to September 11, 2001 the trucking industry employed security measures that were physical in nature as well as practices aimed at securing trucking industry assets against terrorist acts. The former includes locking and sealing devices, terminal security, and use of video surveillance cameras, while the latter includes employee/driver background checks, increased education and training and enhanced compliance with regulations for hazardous materials.

Security measures implemented after September 11, 2001 echo the perceptual changes that threats of terrorism have definitely become the top priority security risk to the trucking industry. While the most common post-September 11, 2001 changes were the establishment of anti-terrorism policies and practices, awareness training, and issuance of IDs, security-related changes have covered a broad range of areas, which we have organized into the following categories (5, 6):

- Procedural Changes
- Employment-Related Practices
- Employee Training Procedures

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[2] Concerns over "Rest stop/parking" and "Accidental contamination" would likely not be considered terrorism-related security threats.

- Physical Security Measures
- Implementation of Technology Measures
- Communication Procedures
- Information Sharing
- Pre-Screening and Pre-Processing Systems
- Security Assessments
- Education and Outreach Efforts
- Legislation

Our objective in grouping post-September 11, 2001 security measures into these topics was to provide structure to a very broad and comprehensive array of topics. However, these categories do overlap in certain areas, which will be described in the remainder of this section. For example, employment-related practices use, in some instances, advanced technologies such as for the Transportation Worker Identification Card.

Security-related initiatives taken since September 11, 2001 have employed both bottom-up as well as top-down approaches. The trucking industry and the American Trucking Association (ATA) have initiated their own ideas to enhanced security, while legislation, and rules and regulations have originated from agencies of the federal government, including the Transportation Security Administration (TSA) and the Federal Motor Carrier Safety Administration (FMCSA).

Changes in Procedures
Procedural changes were most commonly implemented by individual trucking companies. These changes included specific measures such as the development of anti-terrorist policies, security coordination with vendors, re-evaluation of cargo-related security, and improved preparedness. According to the ATA as well as the FBI, procedural security enhancements may also include actions such as not listing products by name on bills of lading or on invoices given to the driver. This view also reflects the position that it is not always necessary to have drivers know what they are hauling nor is it necessary that drivers always have access to loading areas where they are able to see the product they are carrying. Moreover, shipping personnel can be told not to discuss products or operations with drivers and trucking companies can be required to provide identifying information of the driver prior to his/her arrival.

Employment-Related Practices
Such practices include enhanced scrutiny and background checks for existing and new employees, the issuance of identification badges, and stricter discharge clauses. Background checks typically include work history, criminal and reference checks, citizenship status, and reviews of financial records. The combination of measures employed for new hires is strongly correlated with the type of services provided and the cargo carried by the individual trucking company. Moreover, ATA has reported that certain carriers designate specific drivers for specific types of loads, such as hazardous materials, valuable goods shipments, and explosives.

The FMCSA initiated its *Security Sensitivity Visits (SSV)* Program in response to the attacks of September 11, 2001. This program consists of FMCSA conducting onsite visits to motor carriers that transport hazardous materials focusing on carriers transporting hazardous materials in quantities that could potentially pose a significant threat, companies that train drivers, and companies that lease trucks and drivers, and high-risk facilities such as chemical plants and petroleum refineries. The SSVs are intended to discuss methods of security enhancements, increase the level of awareness of hazardous materials carriers to terrorist threats, identify potential weaknesses in carrier security programs, and report potentially serious security issues to the appropriate authorities. FMCSA has completed more than 40,000 SSVs and has issued a report to Congress on the success of this program.

Another example of a security-related employee measure is the *Transportation Worker Identification Card (TWIC)*. The TWIC program, a government initiative issued by the U.S. Department of Transportation under development by the Transportation Security Administration is a credentialing program that provides a uniform and nationwide standard for secure identification of workers across all transportation modes, including the trucking industry. It utilizes a hybrid or dual smart card, which has both a contact and contactless (proximity) communications capability using two separate computer chips. The smart card is used to store the biometric identifiers ─ expected to be fingerprints and iris scans ─ of the individual to whom the card is issued. The card stores the biometric data using cryptological technology to protect the data stored on the card as well as the transmission of that data.

Employee Education and Training Procedures
These procedures have been implemented to improve security awareness and preparedness. Such procedures include the following, which have been initiated by the American Trucking Association members:

- Instructing drivers not to stop and/or render assistance except in the case of clear and obvious emergency situation
- Alerting drivers to potentially deceptive tactics used in truck hijackings
- Emphasizing to all trucking company employees, not only drivers, to stay alert and remain aware of their surroundings at all times, especially when transporting hazardous materials
- Advising truck drivers to notify their supervisors of suspicious shipments or to contact law enforcement to request inspection of shipments.
- Re-assessing specific routes and advising drivers transporting particular hazardous materials to avoid highly populated areas and use alternate routes if feasible to avoid such areas
- Instructing drivers to verify seal integrity at each stop
- Advising drivers to immediately notify central dispatch if seal integrity is compromised, and reconciling the serial number on loaded trailers with the number on the shipper’s documents prior to departure

Physical Security Devices
Such measures have been implemented to improve facility security through means including cameras, video surveillance equipment, security guards/personnel, and security for trucks and their cargo such as locks and seals. For example, an electronic seal (e-seal) is a container locking device that transmits data on container location and status.

Implementation of Technology Measures
In direct response to the attacks of September 11, 2001, implementation of technology measures primarily included the use of cameras, locks and seals, and global positioning satellite systems (GPS). Additional technology system changes either planned for or implemented since the immediate aftermath of the 2001 terrorist attacks may be classified into the following groupings (5, 10, 11, 12, and 13):

- Vehicle Monitoring
    - Closed circuit television (CCTV), digital recording, remote viewing, covert CCTV, and detection devices such as for motion, fire, and burglary sensors.
- Vehicle Inspection
    - Wireless inspection systems based on dedicated short-range communications (DSRC) at 5.9 GHz.
- Cargo Detection
    - Non-intrusive inspection technologies, e.g., x-ray, gamma ray, that can detect WMD including radiological, chemical, and biological type weapons that are inside a container (us treasury advisory committee on commercial operations of the US CUSTOMS SERVICES
    - Non-intrusive technology to electronically detect the presence of persons inside of shipping containers (human occupancy detection)
    - Non-intrusive technology to scan and detect cargo containers for special nuclear material by means of neutron or gamma rays
- Cargo Tracking
    - Includes technologies such as GPS, RFID, barcodes, satellites, and web-based systems that can be used to identify cargo loaded into a container and/or to track the container. Such technologies enables the identification of assets being loaded into a container, the sealing of the container, the tracking of the container, and enables the owner of customers to determine in real-time the location and integrity of the container at, for example, the port of entry, and, if necessary, to alert security or to immobilize the vehicle.
- Access Control
    - Includes technologies to identify and authenticate individuals or vehicles allowed into a restricted area or to authenticate a person to drive a particular vehicle or perform a restricted function such as loading cargo into a container. Include items such as electronic access, gates, electric fences, identification cards (picture badges,

biometrics, smart cards), coded lock and entry, truck and trailer locks, seals and tamper sensors, remote engine shut-off, and identification or password protection for engine start-up.

- Communications
    - Include two-way radios, panic buttons, and cell phones.

Communication Procedures
Improved communication systems and methods between drivers and dispatchers as well as among in-house trucking company staff are also part of the overall response to the perceived and actual security threats. Such systems and methods include having additional meetings to improve awareness and more frequent on-road communications.

Information Sharing Initiatives
Agencies involved in goods movement security collect, store, and analyze different types of data and information. Promoting the sharing of information among agencies can improve the ability of agencies that need certain data or information for security reasons to access it.

Examples of Information Sharing Initiatives include the following:

- *Surface Transportation Information Sharing and Analysis Center (ST-ISAC)*: This center collects, analyzes, and distributes security and threat information from worldwide resources
- *Interagency Border Inspection System (IBIS)*: A database that tracks information on suspect individuals, businesses, vehicles, aircraft, and vessels and makes that information available to law enforcement agencies
- *AASHTO Task Force on Transportation Security*: An AASHTO committee represented by FHWA, state DOTs, and the Military Traffic Management Command that establishes guidance and information sharing practices to 1) assist state DOTs prepare vulnerability assessments of their highway infrastructure assets, 2) develop deterrence/surveillance/protection plans, 3) develop emergency response plans and capabilities for handling traffic for major incidents, and 4) assess and respond to military mobilization needs in each state.
- *Canadian/American Border Trade Alliance (C/ABTC):* A coalition of the public and private sectors involved in US-Canadian trade and tourism dedicated to improving the efficiency of US-Canada border crossings
- *Consular Lookout and Support System (CLASS)*: A name check database that gives overseas US consular officials access to intelligence records to make more informed decisions regarding visa adjudication, which can ultimately improve US border security
- *Freight Transport Security Consortium (FTSC*): An alliance of over 50 companies in the fields of asset tracking, vehicle monitoring, emergency response, truck and rail management systems, equipment finance, and insurance to develop solutions to the threat of terrorist attacks on the goods movement transportation supply chain

- *Integrated Automated Fingerprint Identification System (IAFIS)*: A system that allows federal, state, and local criminal justice agencies to electronically transmit fingerprint information to the FBI, which can improve border security by giving law enforcement agencies more timely information about individuals at border crossings with potential criminal or terrorist backgrounds
- *Automated Biometric Identification System (IDENT)*: A system allowing the Customs and Border Protection staff to match fingerprints and photos of immigration violators to a national database, which improves border security by allowing Customs to identify and track individuals trying to reenter the US

Pre-Screening and Pre-Processing Systems
These systems are designed to improve goods movement security and maintain goods movement efficiency by screening cargo and processing customs paperwork from authorized shippers and carriers before a shipment arrives at an international gateway (seaport, airport, border crossing).

Examples of these systems include the following:

- *Container Security Initiative (CSI)*: A program to tighten and expand cargo-reporting requirements by pre-screening containers before reaching US ports
- *Border Release Advanced Screening and Selectivity (BRASS)*: A cargo processing system using barcode technology to expedite release of high-volume shipments at borders
- *Customs Automated Forms Entry System (CAFES)*: A system using barcode technology to reduce paperwork and waiting time at the border
- *Customs Trade Partnerships Against Terrorism (C-TPAT)*: A joint government and business initiative to protect cargo security entering the US while improving flow the trade. This program allows low-risk carriers to receive streamlined border clearance approval
- *Free and Secure Trade (FAST)*: A bilateral clearance process between Canada and the US for known low-risk shipments handled by C-TPAT-approved motor carriers.

Security Assessment Programs
Government security agencies and the trucking industry have formed partnerships to identify existing vulnerabilities in trucking supply chains.

Examples of Security Assessment Programs include the following:

- *Operation Safe Commerce (OSC)*: A program to fund business initiatives that identify existing supply chain weak spots and develop means to enhance cargo security
- *Carrier Initiative Program (CIP)*: A program designed to assist carriers to enhanced security at international and domestic terminals
- *Business Anti-Smuggling Coalition (BASC)*: A voluntary and business-led alliance complementing the CIP to fight against terrorist-related smuggling

- *America's Counter Smuggling Initiative (ACSI)*: A program building upon the work of the CIP and the BASC by expanding these security programs throughout Mexico, Central America, and South America
- *Land Border Carrier Initiative Program (LBCIP)*: A program to counter smuggling of illegal cargo via commercial land carriers by enhancing their security at international and domestic terminals and on-board their trucks

Education and Outreach Efforts
Several government agencies, shippers, carriers, and other goods movement stakeholders have increased their level of participation in forming new multi-organizational as well as multi-jurisdictional alliances, coalitions, task forces, and trade and industry groups. Such new organizational entities help provide security-related educational and outreach opportunities to member agencies and other stakeholders.

An example of Education and Outreach Efforts is the following:

- *Anti-Terrorism Action Plan (ATAP)*: A joint trucking industry-government effort to evaluate security risks to the trucking industry and a plan to train truck drivers to identify and report any suspicious activities that could be related to terrorism through the ATA's Highway Watch Program

Legislation
There are many federal security programs that have been proposed and/or initiated since the September 11, 2001 terrorist attacks. The range of these programs, all of which have some direct or indirect linkage to the trucking industry, covers topics ranging from the development of security programs, personnel management, the tracking of vehicles, cargo, or cargo type (specific commodity), or the reporting of security-related information.

The following pieces of security-related legislation have been enacted by Congress since September 11, 2001 (8):

- U.S. Patriot Act: Develops a range of trucking security programs including the truck driver commercial driver license hazmat endorsement background check
- Trade Act of 2002: Advance electronic notification of cargo information
- Maritime Transportation Security Act: Strengthens of CTPAT, developing a "Secure System of Transportation"
- Border Security Act: Strengthens border agencies resources, requiring close coordination among them
- Bioterrorism Act: Food and Drug Administration (FDA) rules on facilities registration handling regulated cargo, import notification and recordkeeping rules
- Safe Explosives Act: Establishes criteria disqualifying drivers from transporting explosives
- Aviation Transportation Security Act: Requires security plans and security threat assessments of indirect air carriers, among others

- Goods Movement Act of 2005: Calls for investment to expand the freight transportation gateways in this country, including expanding security considerations, but no mention of any technologies
- Surface Transportation Research and Development Act of 2005: Requests appropriations for increased research into areas of construction materials, methods, and expansion of existing surface transportation infrastructure
- Secure Domestic Container Partnership Act of 2005: Calls for the establishment of an 'empty shipping container sealing pilot program' to ensure that empty shipping containers are made secure in their transshipment after delivery of goods. This may offer utilization of smart card technology, but it is not called for in the legislation
- Rail and Public Transportation Security Act of 2005: Addresses appropriations for improvements in rail and public transportation facilities, but does not directly address surface transportation involved with cargo or supply chains.

"Further, it is apparent that if the United States is to successfully protect and defend itself against the dangers of terrorism and asymmetric warfare, an integrated strategy involving close cooperation among all relevant agencies and organizations will be required. Effective and efficient utilization of all available knowledge, experience, and personnel will be imperative if these threats are to be countered" (14).

The lesson from this quote above appears to have been taken very seriously as a common thread running through most if not all of these security-related measures and programs is the recognition of how crucially important it is to form multi-organizational alliances, coalitions, and partnerships to enhanced the chances of success for such implemented initiatives. The exact nature of the alliances and partnerships depend on the initiative's objective, which helps determine whether multiple countries or the public and private sectors, or government and business, or members of the trucking industry or some combination of these stakeholders are working together.

6: GAPS IN THE LITERATURE: WHAT WE DO NOT KNOW

The ultimate and most significant objective resulting from implementing all these security-related measures is clear and unambiguous:

- Reduce the vulnerability and risk exposure of the U.S. trucking industry to acts of terrorism

As has been reported thus far in this document, a large number of measures, initiatives, and programs have been put into practice, especially over the past five years, with the intention of achieving this objective. Thus far there have been accomplishments that serve as initial-stage successes to eventually get to the ultimate objective, which include the following (6):

- The AASHTO Task Force on Transportation Security has completed a national survey of state DOTs' security needs; completion and distribution of its Vulnerability Assessment and Emergency Response Planning Handbook for state DOTs; documenting case studies of September 11, 2001 experiences in Michigan, Virginia, and New York.
- From the ATAP program, more than 1 million truck drivers have received security training through the Highway Watch Program and the ATA has developed a color-coded security threat alert system that helps trucking companies identify their security needs at various threat levels.
- Over 1,000 businesses have joined the BASC Program as participants.
- There are over 4,800 participants in CIP.
- The C-TPAT program currently has more than 1,800 participants.
- E-seals were successfully tested in 2002 on 30 containers moving between Japan, the Port of Tacoma, and the Blaine, WA international border crossing.
- The IAFIS system has improved response times in transmitting fingerprint information to the FBI.
- The LBCIP program has 825 participants.

While such programs' objectives may have been met, thus far the literature is lacking in documenting more quantitative assessments of the 1) extent of the terrorist threat to the trucking industry and 2) effectiveness of implemented security-related measures. For example, as previously discussed in Section 3, while there are surveys indicating the trucking industry's perceived threats, there's no central database for the collection of such data, whether it be vehicle thefts, cargo thefts, security breaches by drivers or outsiders. Moreover, it would be informative to know how the volumes of such thefts are distributed among the trucking industry according to truck company size, type of cargo, and other measures. However, acquiring the required input data will be challenging. Ways to measure the effectiveness of the programs that have been implemented since September 11, 2001 could use before/after studies, benefit/cost analyses, or match-pair treatment studies. Again, obtaining the crucially important input data will not be an easy task.

Potential fallout from implementing security-related measures for the trucking industry, especially at ports of entry and international borders, are delays associated with intensified inspections, and such delays could undermine the competitiveness of exports by increasing company transaction costs. Thus there are tradeoffs between efforts to enhance security of the trucking industry and the necessary efficiency of trade to promote sustained expansion and integration of the global economy. Overseas buyers might avoid ports where there is a heightened risk that products will arrive damaged, spoiled, or late and rapid, hassle-free immigration controls are essential to both global business and tourism. Investigating this tradeoff more quantitatively would be helpful in the overall assessment of the effectiveness of security-related measures. As discussed in Section 5, the FAST Program allows low-risk carriers to receive streamlined border clearance approval and so has the potential to reduce border crossing and shipment delays. Measuring the effectiveness of FAST, however, has, thus far, not been performed.

The most well-documented study of the effects of implemented security measures was the Hazardous Material Safety and Security Field Operational Test (FOT) and Evaluation conducted over a two-year period starting in September 2002 and culminating in a six-month field testing of multiple technologies (15). The purpose of the FOT was to quantify the security costs and benefits of an operational concept that applies technology and improved enforcement procedures to the transport of hazardous materials and was scoped to address the following risk areas: driver verification, off-route vehicle alerts, stolen vehicles (both tractors and trailers), unauthorized drivers, cargo tampering, and suspicious cargo deliveries. The FOT focused on deploying technologies that addressed the 23 separate functional requirements established by the US DOT.

A security benefits assessment was performed and the independent evaluator stated that "Assessing the potential security impacts (consequence reduction) related to the HAZMAT FOT presented a significant evaluation challenge for two key reasons:

1. There is little or no event data on which to reliably baseline the level of HAZMAT-based terrorist attacks or to provide actuarial data in which to predict a statistically significant number of actual terrorist actions in the future.
2. A method needed to be developed that would translate field test performance and user acceptance information into monetized risk reduction terms.

Consequently, the Evaluation Team developed a unique analytical framework to assess potential benefits. This framework built upon traditional vulnerability assessment techniques, combined observations from both real-world and simulated operations within the FOT framework, and made use of expert judgment and sensitivity analysis. The core of this framework is expressed in a classic vulnerability assessment equation:

Threat x Vulnerability x Consequence = Cost

where 'Cost' is the financial impact of HAZMAT-based terrorist attacks. By applying this formula both before and after the deployment of technologies, it was possible to determine the likely security impacts of the test technologies and to express these impacts in quantifiable, economic terms." (15).

This methodology should be studied to determine its applicability to assessments of benefits vis-à-vis other security-related measures and programs. The full set of reports on the FOT and the Evaluation may be obtained from (15).

7: CONCLUSIONS

The focus of security measures relative to the trucking industry has dramatically changed since the terrorist acts of September 11, 2001. Before September 11, 2001 the focus was more on vandalism and the theft of trucks and/or its cargo, as well as interdicting the transport of illicit cargo including people and contraband. A multitude of players at multiple governmental levels ─ international, national, state, and local ─ as well as from the private business sector are now involved; however, their participation is enhanced by a substantial degree of coordination and cooperation as they pursue their security-related activities with new alliances, coalitions, and partnerships. While there is a substantial volume of security-related initiatives and programs that have been implemented to better understand the threats to, the vulnerability of, and methods to enhance the security of the trucking industry, such programs ─ most of which have been implemented only a few years ago ─ have generally not been quantitatively assessed in terms of the benefits and costs. More careful quantitative investigations in this area are clearly needed.

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APPENDIX D

Regulations on Heavy-Duty Truck Emissions and Barriers to Enforcement and Compliance in California: A Review of the Literature

PATH TO 6105

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1.0 INTRODUCTION

The state of California is home to the world's third busiest ports, the ports of Long Beach and Los Angeles in San Pedro Bay, as well as the second largest border crossing with Mexico in the U.S. As a result, California's roadways carry more commercial vehicle truck traffic than any other state in the U.S., and nationally, this traffic is expected to grow by 50 percent in 2020 (FHWA, 2006). Commercial vehicle trucks use diesel engines because they are 25 to 35 percent more fuel-efficient and have greater durability than gas engines, but diesel exhaust releases 100 times more particles of soot than a gas engine under the same conditions (U.S. Government Accountability Office, 2004; American Lung Association, 2000). Diesel engines are responsible for approximately 66 percent of particulate matter almost 26 of nitrous oxides in the air from on-road sources (American Lung Association, 2000). Diesel exhaust has serious effects on human health; it is classified by the State of California as a carcinogen and contains forty hazardous air pollutants listed by the U.S. Environmental Protection Agency (EPA). Not surprisingly, California has four of the top 25 metropolitan areas in the U.S. with the greatest health impacts due to diesel: Los Angeles, San Francisco-Oakland-Fremont, San Diego-Carlsbad-San Marcos, and Riverside-San Bernardino-Ontario, ranking two, seven, 21, and 25 respectively (Clean Air Task Force, 2006).

Because of their serious health effects, the gaseous emissions from diesel engines have been the subject of increasingly strict regulation for more than 30 years, yet these emissions remain a problem. The large scope and high cost of enforcement required to ensure compliance with current diesel emissions regulations on engine manufacturers and commercial vehicle operators raise questions about its effectiveness. The history of compliance with regulations on diesel emissions is rife with examples of deliberate attempts by engine manufacturers and commercial vehicle operations to skirt these regulations.

In this paper, the literature is reviewed to examine the magnitude of diesel emission health effects as well as the challenges to and efficacy of the enforcement of diesel emissions regulations. The paper begins with a discussion of the body of evidence on the health effects of diesel emissions. Next, background is provided on the agencies responsible for regulating and enforcing compliance in California and the nation. This is followed by a description of the regulations on diesel emissions and enforcement procedures as well as an analysis of the barriers to effective of enforcement. Next, the voluntary and incentive based programs sponsored by California and federal agencies to promote compliance are presented. The paper concludes with a discussion of future regulatory and enforcement challenges to diesel emissions posed by the North American Free Trade Agreement (NAFTA) and an assessment of future prospects for enforcement and compliance in California.

2.0 HEALTH EFFECTS

2.1 Composition of Diesel Exhaust Emissions

Emissions can come from the tailpipe of diesel engine trucks as well as via crankcase ventilation, which occurs when exhaust blown into the crankcase is vented to prevent buildup of pressure (Hill, 2005). The exhaust released is relatively heterogeneous, consisting of a mixture of particles and gases (EPA, 2002). The composition of the mixture varies depending on engine operating conditions and the type of fuel used (EPA, 2002). Forty of the hazardous air pollutants listed by the EPA can be found in diesel exhaust and 15 of those listed by the International Agency for Research on Cancer (Hill, 2005).

The particles and gases emitted from diesel engines that contribute to ill health are (EPA, 2002; EPA 2006a):

- Hydrocarbons, including aldehydes (formaldehyde, acetaldehyde, acrolein), benzene, 1,3-butadiene, polycyclic aromatic hydrocarbons, and nitro-polycyclic aromatic hydrocarbons.
- Nitrous oxides (or "NO_x"), which include NO, NO_2 and other oxides of nitrogen
- Carbon monoxide (CO), an odorless, colorless gas that is formed when carbon is not completely burned.
- Sulfur dioxide (SO_2) gases, which are formed during the burning of fuel containing sulfur and during certain industrial processes. SO_2 is also a precursor to $PM_{2.5}$.
- Particulate matter (PM) is divided into two categories:
  - Coarse PM (PM_{10}), which is between 10 micrometers and 2.5 micrometers in diameter, and At its core, PM consists of "elemental carbon and absorbed organic compounds, as well as small amounts of sulfate, nitrate, metals, and other trace elements" (EPA, 2002, p. 1).
  - Fine PM ($PM_{2.5}$), which is less than 2.5 micrometers in diameter.

2.2 Studies of Diesel Emissions and Health

Of these substances, PM_{10} and $PM_{2.5}$ have been the focus of the majority of research on health effects. When PM is absorbed by the lungs, and it can be cleared via the immune system, but this process can take months or years, and often particles remain lodged in the lungs. PM_{10} tends to land downwind from emission points, whereas fine PM can travel farther and penetrate deeply into the human body. PM often becomes coated with teratogenic or carcinogenic substances, such as formaldehyde, which they transport deep into the lung tissue (EPA, 2002). $PM_{2.5}$ is small enough that it can be is absorbed into the bloodstream, where it can initiate an inflammatory response that disrupts heart rate, increases blood clotting, and can ultimately lead to a heart attack (Clean Air Task Force, 2006; Hill, 2005).

The majority of research has evaluated health effects due to long-term exposure to diesel exhaust, such as lung cancer and cardiovascular deaths. More recently, an increasing number of epidemiologic and experimental studies have assessed the effects of short-term exposure to diesel exhaust on respiratory and immune systems (Health Effects Institute, 2003). Many of these studies have shown that short-term exposure to PM from diesel exhaust increases risk of daily mortality, respiratory problems, and asthma exacerbation (Health Effects Institute, 2003).

2.3 Challenges Involving Exposure Assessment

There are several issues involving exposure assessment that present challenges in assessing diesel emissions' effect on health. First, a commonly used measure of exposure in health studies of diesel emissions is elemental carbon (EC), which is also measured as black smoke. However, EC is found in other emissions besides those from diesel, so there is no guarantee that samples of EC in the air are from diesel. In addition, EC content differs depending on operating conditions and the type of engine (Health Effects Institute, 2003). Another method of assessing health effects from emissions is to measure the traffic density in regions where people are most likely to be exposed. However, these measures are qualitative at best since they can be skewed by the impact of bus depots or highways nearby. Long-term studies of exposure are challenging in that exposure must be reconstructed over a long period of time (Health Effects Institute, 2003).

A major challenge with epidemiologic studies of diesel emissions and health is that there is no marker characteristic of PM that can be used to measure exposure, and it is difficult to measure exposure retrospectively (Health Effects Institute, 2003). Experimental studies have also evaluated the effect of diesel upon health in animals and provide repeated evidence that diesel emissions exposure leads to lung cancer. However, the inference from such studies may not be relevant to humans, who have different path physiology and are subject to much lower levels of exposure than those used in experimental studies (Health Effects Institute, 2003). While numerous studies have examined the health effects of individual particles that are known to be emitted from diesel engines, considering the total effects of studies done on individual particles can lead to misleading and overestimated effects because pollutants are correlated (Künzli et al., 2003). The following sections cover a few of the seminal studies measuring health effects from exposure to large truck traffic as well as air pollution in general.

2.4 Air Pollution and Health

Studies of air pollution and health have shown small risk of mortality and ill health at the individual level. For instance, an increase of 10 ug/m^3 of PM_{10} leads to an increase in risk of death that is less than one percent for an individual. However, significant health effects have been found when population level exposure is considered. In 2000, Künzli et al. conducted the first study of air pollution on health across several countries, including Austria, France, and Switzerland. Their analysis considered mortality, respiratory and cardiovascular hospital admissions, incidence of chronic bronchitis, episodes of bronchitis in children, restricted activity days, and asthma attacks. In order to estimate exposure, Künzli et al. reviewed the literature and derived exposure-response functions from selected studies and then calculated a meta-analytical health effect using the findings of these studies weighted for differing variances. The authors found that six percent of deaths in the region, or 40,000 deaths, were attributable to air pollution. Of these, motorized traffic accounted for 25,000 incident cases of chronic bronchitis in adults, over 290,000 episodes of bronchitis in children, 500,000 asthma attacks, and over 16 million person-days of restricted activities. In addition, traffic was responsible for 28 percent of the annual mean PM_{10} in low concentration areas (10-15 ug/m^3) and 58 percent in higher concentration areas (40 ug/m^3).

2.5 Residential Truck Emissions and Health

In a study of traffic in Hunts Point, New York City, Lena et al. (2002) measured emissions of elemental carbon and $PM_{2.5}$ on sidewalks and assessed spatial variations in concentrations with respect to traffic density by vehicle type. Hunts Point is located on a peninsula in the South

Bronx and is home to 10,000 residents, 3,000 of whom are children. The two main ethnic groups in the area are Latinos (73 percent) and African Americans (25 percent). A key feature of the region is that it is a hub for freight transportation between New York, New Jersey, and Connecticut. The study was initiated in response to residents' concerns about exposure to traffic emissions. After comparing emissions from cars, light trucks, and large diesel trucks, Lena et al. (2002) found the highest correlation with emissions of elemental carbon and $PM_{2.5}$ from large diesel trucks (r = 0.92, r = 0.72).

A study in the Netherlands by Brunekreef et al. (1997) examined lung function among children living in six areas near major motorways. Air pollution from truck traffic was assessed by measuring the distance from children's homes to motorways and traffic density (or counts of the number of passing trucks) on motorways. In addition, PM_{10} and NO_2 concentrations were measured inside schools of children in the study. Researchers found a clear exposure-response relationship between distance from home to motorway and child's lung function. Children who lived within 100 meters of motorways or near the highest truck traffic densities had decreased lung function compared to children living in other areas.

A later study in the Netherlands by Janssen et al. (2003) also measured respiratory health of children attending schools within 400 meters of a motorway. Distance between schools, homes, and motorways was measured, and traffic counts were used to assess exposure levels. Health effects assessed in the study included bronchial hyper-responsiveness and allergic sensitization of airways. Researchers found that truck traffic and its associated air pollutants were associated with chronic respiratory symptoms among children who lived close to motorways.

While these studies are prone to the same challenges in exposure measurement discussed above, they are better approximate true exposure conditions than experimental studies using animals and studies of individual pollutants health effects. In addition to these studies, a review of diesel exhaust emissions research by the Health Effects Institute, an independent research institute partially funded by the EPA, discusses other relevant studies. Lung cancer has received much of the research attention, mainly through occupational studies of railroad workers and truck drivers have shown a relatively consistent, though weak, association between exposure to diesel exhaust and lung cancer (Health Effects Institute, 2003). More recently, research has focused on asthma exacerbation and immune response. One problem with these studies is that were conducted in different locations using different estimates of exposure, including measures of traffic density and distance to roadways. Many of these studies lacked exposure information at the individual level and failed to control for possible confounding factors. Overall, the studies show that the people with asthma likely have a different physiological response to diesel exhaust than healthy individuals. Further research is needed to better assess the relationship between diesel emissions, asthma, and allergies.

2.6 Vulnerable Populations and Communities

In general, health effects from diesel exhaust emissions are most serious among children, the elderly, and people with preexisting heart and lung conditions. Most children are also more active than adults, have a higher respiratory rate, and spend more time outdoors, so the effects of diesel emissions are particularly egregious (Gauderman et al., 2000). One of the most comprehensive studies on the health effects of air pollution on children is the Children's Health Study. Started in 1993, the study followed 6,000 children living in Southern California. The study found that children living in communities with higher levels of NO_2 and PM experience 10 percent slower lung function growth (Künzli et al., 2003). Children with asthma living in such communities suffered from more bronchitis as well as persistent phlegm production (Künzli et al., 2003).

In addition, residents of communities near sources of concentrated diesel emissions, such as ports and major truck routes, have also been shown to be at significant risk. Most of these communities are composed of minority and economically disadvantages populations. In California, the serious health effects have been documented on several communities with close proximity to truck traffic and West Oakland, Bayview Hunters Point in San Francisco, and Mira Loma (near Riverside).

West Oakland, home to approximately 24,000 residents who are primarily African American and of low socioeconomic status, is surrounded by three freeways, the Oakland Army Base, and the Port of Oakland, which is the fourth busiest port in the country (Costa et al., 2002). With over 20 truck-related businesses operating in the area, West Oakland had 2,941 truck trips per day in 2000 (The Coalition for West Oakland Revitalization et al., 2004). Many of these trucks idle in residential areas before or after their transactions at the port (The Coalition for West Oakland Revitalization et al., 2004). As a result of the high rate of emissions from these trucks, compared to the rest of the state, average diesel emissions in West Oakland are over 90 times higher per square mile (The Pacific Institute, 2003). In West Oakland, emissions of diesel particulates per person are six times higher than in the rest of Alameda County (The Pacific Institute, 2003).The health effects of this exposure are stark: children living in West Oakland have a seven-fold higher likelihood of hospitalization due to asthma than an average child living in California (The Coalition for West Oakland Revitalization et al., 2004).

In the Bayview Hunters Point in San Francisco, like West Oakland, the majority of residents are minorities: 48 percent African American, 1.3 percent American Indian, 23 percent Asian and Pacific Islanders, and 17 percent Latino (Bayview Hunters Point Mothers Environmental Health and Justice Committee et al., 2004). Almost 40 percent of residents have an annual income that is below $15,000, and the unemployment rate in the area is twice that of San Francisco's overall rate (Bayview Hunters Point Mothers Environmental Health and Justice Committee et al., 2004). Bounded by the west side of the San Francisco Bay, U.S. Highway 101, and Highway 280, the neighborhood is subject to heavy emissions. With no major thoroughfare connecting industrial areas to the freeway, trucks must drive through residential areas to reach the commercial section of Third Street (San Francisco Planning Department, 2006). City zoning also plays a role in heavy emissions: more than half of land zoned for industrial use in San Francisco is in the Bayview Hunters Point (Bayview Hunters Point Mothers Environmental Health and Justice Committee et al., 2004, p. 5). The area of Bayview Hunters Point most affected by emissions lies east of Third Street, where approximately 12,000 residents live near "heavy industry, power plants, and truck traffic" (Bayview Hunters Point Mothers Environmental Health and Justice Committee et al., 2004, p. 5). Sharing space with heavy industry and passing trucks results in an increased burden of disease among residents. Asthma affects 10 percent of Bayview Hunters

Point residents, the national rate is 5.6 percent, and as many as 15.5 percent of children suffer from asthma.

3.0 INSTITUTIONAL BACKGROUND

In this section, background is provided on the agencies responsible for the implementation and enforcement of diesel emission regulations federally and in California.

3.1 Federal Institutions

Gaseous emissions from diesel engines were first regulated nationally when the EPA was established in the 1970s, and particle emissions were later regulated in the 1980s (EPA, 2002). A U.S. Government Accountability Office (GAO) analysis of the EPA's efforts to meet requirements promulgated by the Clean Air Act amendments of 1990 found that many aspects of the Air Toxics Program established under the act were completed late or have yet to be completed (GAO, 2006). For instance, EPA was supposed to complete a review of residual risk posed by air pollutants by 2008, but it will not be able to complete them until 2012 at the earliest, which will prevent them from collecting information on potential health effects that could merit regulation (GAO, 2006).

One challenge in addressing diesel-related emissions is that EPA's programs involving air quality are parsed apart into programs that address different components of diesel emissions. These programs include an air toxics program, smog program, and particulate matter program. Because of limited funding, EPA must choose to focus on areas with the greatest perceived health risk. Since there is less comprehensive scientific information available about the health effects of air toxics, its program experienced a drop in funding from 18 to19 percent in the 2000 to 2003 period to 12 percent by 2005 (GAO, 2006, p. 5). The result is that the air toxics program has made less progress achieving its goals than in the smog or PM related programs because it is considered a lower priority (GAO, 2006).

EPA must consider the concerns and interests of numerous stakeholders, such as health groups, industry associations, energy groups, and environmental groups, which sometimes have conflicting goals. According to the GAO, the air quality program's "agenda is largely set by external stakeholders," such as environmental advocates, who "file litigation when the agency misses a deadline" (GAO, 2006, p. 5). On the other hand, industry stakeholders have attempted to block the passage of new regulations. For instance, when EPA proposed a rule to impose more strict smog controls, a series of court challenges, partially brought by the American Trucking Association, halted efforts from 1997 to 2001, when the Supreme Court ruled that EPA had the authority to set the regulation (Wall Street Journal, 2003). The rule changed the period of measuring ozone from one hour to eight hours. In addition, industry stakeholders have pressured the EPA to delay implementation deadlines or have purposefully evaded laws and deadlines, as will be described in more detail below.

3.2 California Institutions

The California Air Resources Board (CARB) is known for passing landmark regulations that set the tone for the national air quality policy agenda. Because of the severity of air quality problems in California, it is the only state that is allowed to create its own standards for mobile source emissions and fuels according to the Clean Air Act. The CARB is comprised of 11 members selected by the current Governor. There must be one member from the San Diego Air Pollution Control District, San Francisco Bay Area Air Quality Management District, San Joaquin Valley Unified Air Pollution Control District, South Coast Air Quality Management District, and one other air district. Three must be members with a background in automotive engineering, science, agriculture or law, medicine or health effects, and air quality control (CARB, 2004). Finally, there are two public members. The composition of the board is intended to bring experts with diverse interests and backgrounds to the CARB.

Despite the varying backgrounds and interests of its members, the CARB has successfully set regulations under both Republican and Democratic governors during periods of both recession and economic growth (Martin, 2006). Rather than replacing the entire board with new administration, incoming governors have always left several members on the board unchanged, which allows for greater continuity and efficiency as well as authority (Martin, 2006). The board is also able to engage stakeholders while developing regulations to avoid delays of implementation and to minimize noncompliance (Martin, 2006).

Another challenge California faces in being the first to pass new emissions regulations is that other states and countries on its borders do not necessarily pass the same emissions standards, despite EPA recommendation that other states use the same opacity set points as California to "ensure uniformity across state lines" (McCormick et al., 2003, p. 631). Of the states bordering California, Nevada is the only one with a statewide emissions testing program, some regions of New Mexico have a periodic testing program, and Oregon has no program (Energy and Environmental Analysis, 2004). In addition, as discussed below, the potential influx of trucks from Mexico, where emissions standards are less stringent, poses a threat to California's air quality. The effectiveness of regulations to prevent high-emitting trucks from entering California has yet to be determined.

4.0 REGULATIONS ON DIESEL EMISSIONS

This section discusses the federal and California state regulations on manufacturers of engines for heavy-duty diesel trucks. The major regulations related to emissions reductions require engine manufacturers to test emissions prior to sale, engine certification, and truck operators to use fuel designed to minimize emissions. Besides the fuel regulations discussed above, there are no mandatory regulations upon operators of heavy-duty diesel engine trucks, but there are voluntary emissions evaluations programs, which will be discussed in a later section.

4.1 Regulations on Engine Manufacturers

In the U.S., engine manufacturers are responsible for complying with vehicle and engine emissions standards promulgated by the EPA (GAO, 2004). Before engines are sold, manufacturers “must apply for an EPA Certificate of Conformity” and show that engines will meet emissions standards during their useful life, which could be up to 365,000 miles for heavy-duty engines (EPA, 2006b). In their application for certification, manufacturers must submit “weighted brake-specific emissions data … for all pollutants for which a brake-specific emission standard is established,” “values of all emission-related engine control variables at each test point,” and “a statement that the test results correspond to the test engine selection criteria” (Federal Register, 2005, p. 40433). Engines are chosen for emissions testing based on groupings of engine types or “families” (Title 40 Code of Federal Regulations). Within each family, one engine of each type of exhaust emission control system is tested for smoke and gas emissions (Federal Register, 2005). Test procedures require manufacturers to run cold-start and hot-soak test intervals to calculate the total emission mass and to determine brake-specific emissions (Federal Register, 2005). For each engine family, manufacturers must determine “the number of hours at which the engine system combination is stabilized for emission-data testing” (Federal Register, 2005, p. 40432).

In 2001, under the 2007 Heavy-Duty Highway Rule, EPA set Not-To-Exceed (NTE) requirements for heavy-duty diesel engines starting in model year 2007 which set a ceiling for the amount of emissions for regulated pollutants (Title 40 Code of Federal Regulations, 2000). Upon EPA’s request, engine manufacturers are required to submit a “detailed description of all testing [and] engineering analysis” that their engines comply with NTE requirements “under all conditions which may reasonably be expected to occur in normal vehicle operation and use” at the time of certification (Title 40 Code of Federal Regulations, 2000). Manufacturers must be able to meet NTE requirements “under any engine operation conditions that could reasonably be expected to be seen by that engine in normal vehicle operation and use, as well as a wide range of real ambient conditions” (Title 40 Code of Federal Regulations, 2000). EPA’s emissions standards for heavy-duty vehicle engines are defined in Title 40 (Protection of Environment) of the Code of Federal Regulations Parts 85 and 86. The new NTE requirements limit emissions for PM to 0.01 g/bhp-hr and NO_x to 0.20 g/bhp-hr. The CARB also sets its own emissions standards specifically for heavy-duty diesel engines. Table 1 presents EPA and CARB emissions standards for heavy-duty diesel engines.

Table 1 EPA and CARB Emissions Standards for Heavy-Duty Highway Compression Ignition Engines

	Year	CO (g/bhp-hr)	Idle CO (percent exhaust gas flow)	HC (g/bhp-hr)	NMHC + NOx (g/bhp-hr)	NOx (g/bhp-hr)	PM (g/bhp-hr)	Smoke (percentage)
Federal	1990	15.5	0.5[a]	1.3	-	6.0	0.60	20/15/50
	1991-93	15.5	0.5[a]	1.3	-	5.0	0.60	20/15/50
	1994-97	15.5	0.5[a]	1.3	-	5.0	0.25	20/15/50
	1998	15.5	0.5[a]	1.3	-	4.0	0.10	20/15/50
	2004-2006	15.5	0.5[b]	0.5	2.4	2.0	0.10	20/15/50
	2007+	15.5		0.14	0.14	0.2[d]	0.01	20/15/50
California	1987-90	15.5	0.5[b]	1.3/1.2[c]	-	6.0	0.60	20/15/50
	1991-93	15.5	0.5[b]	1.3/1.2[c]	-	5.0	0.25	
	1994+	15.5	0.5[b]	1.3/1.2[c]	-	5.0	0.10	
	1994-95	15.5	0.5[b]	1.3/1.2[c]	-	5.0	0.07	
	1996+	15.5	0.5[b]	1.3/1.2[c]	-	4.0	0.05	

NMHC = nonmethane hydrocarbon
[a] This standard applies to engines for model years: methanol/1990+, natural gas and LPG/1994+.
[b] This standard applies to engines utilizing exhaust aftertreatment technology.
[c] The first number is the THC standard and the second number is the NMHC standard. Manufacturers of diesel, natural gas, or LPG engines may choose to certify to the total HC standard or the optional NMHC standard. The NMHC standard applies to 1990+.
[d] Flat limit phases in in 2010.
Source: U.S. Environmental Protection Agency (1997, September). Emissions Standards Reference Guide for Heavy-Duty and Nonroad Engines. Accessed September 2, 2006, from http://www.epa.gov/otaq/hd-hwy.htm
Emission standards and supplemental requirements for 2007 and later model year diesel heavy-duty engines and vehicles. Title 40, *Code of Federal Regulations,* Pt. 86.007-11.
U.S. Environmental Protection Agency. (2002). Health Assessment Document for Diesel Engine Exhaust. Retrieved October 1, 2006, from oaspub.epa.gov/eims/ eimscomm.getfile?p_download_id=36319
Jacobs, P.E. (2005). NAFTA/Mexican truck emissions overview. California Air Resources Board. Retrieved October 1, 2006, from www.arb.ca.gov/msprog/hdvip/ bip/naftamextrk.pdf

EPA has recommended certain fleet maintenance practices to minimize emissions and optimize fuel economy, but these practices are not regulated or enforced (U.S. Environmental Protection Agency, 2006c). These practices include the following:

1. Replacing intake air filters and monitoring fuel and oil consumption,
2. Repairing all exhaust leaks,
3. Exercising caution when considering the use of fuel additives,
4. Retaining engine profile information, and
5. Monitoring engines and fuel systems for leaks.

4.2 Fuel Regulations

The new emissions standards require manufacturers to improve the technology of their engines as well as purchase fuel for these engines that reduce emissions. Manufacturers must make engines with “high-efficiency catalytic exhaust emission control devices or comparably effective advanced technologies” (EPA, 2000). These engines must be run with diesel fuel with no more than 15 ppm of sulfur, or “ultra-low sulfur diesel” (ULSD). Such diesel contains 97 percent less sulfur than the diesel currently being used (EPA, 2000). The EPA estimates that once the ULSD fuel regulation is fully implemented, there will be an annual reduction in 2.6 million tons of NO_x and 110,000 tons of PM (EPA, 2006d).

The CARB also recently passed similar regulations requiring the use of ultra-low sulfur diesel. Previously, diesel was allowed to have no more than 500 ppm sulfur by weight, but as of June 2006, in California, "no person shall sell, offer for sale, supply or offer for supply any vehicular diesel fuel having a sulfur content exceeding 15 ppm by weight" (CARB, 2004a, p. 1). Both the Federal EPA and CARB fuel requirements were phased in during 2006.

5.0 ENFORCEMENT PROCEDURES AND CHALLENGES TO REGULATION OF DIESEL EMISSIONS

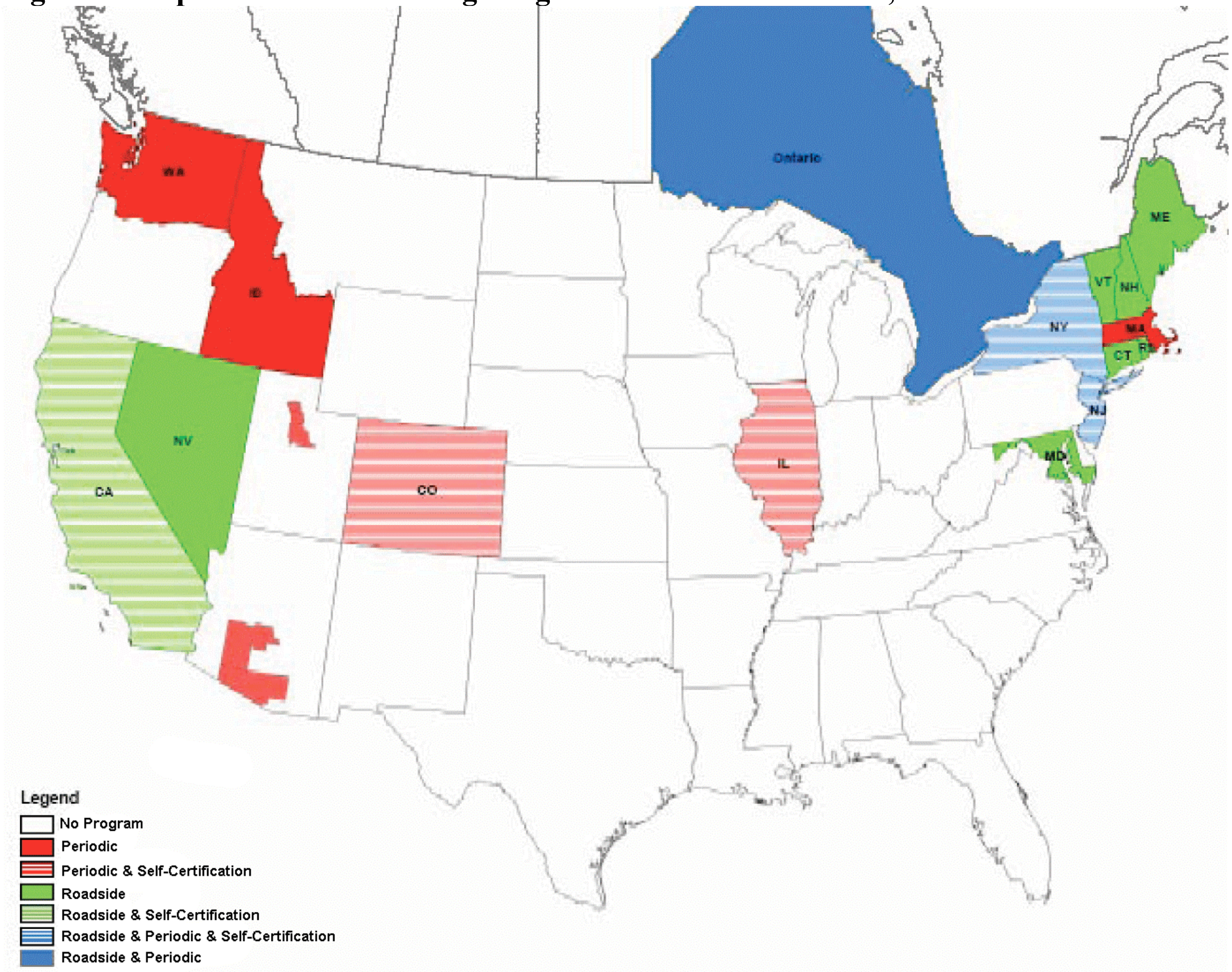
Federal enforcement procedures on heavy-duty diesel engines mainly focus on manufacturers' role in ensuring their engines meet standards before sale, monitoring the operations of their engines in use, and reporting any emissions-related malfunctioning to the EPA. The manufacturers and engine operators bear the brunt of enforcement activities, although EPA does conduct inspections of manufacturing facilities and investigations of violations when suspected.

Some states have their own enforcement procedures, which aim to limit harmful emissions that occur while vehicles are running and evaporative emissions when vehicles are not running (Energy and Environmental Analysis, 2004). There are three main types of programs:

1. Roadside inspection, in which sample of trucks at various locations are tested for smoke opacity;
2. Periodic inspection, in which trucks registered in certain areas undergo annual or biennial inspections at an inspection facility; and.
3. Self-certification, in which truck fleet owners conduct testing at their maintenance facilities. (Energy and Environmental Analysis, 2004)

The distribution of these programs in the U.S. and Canada are shown in Figure 1.

Figure 1 Map of Emissions Testing Programs in Canada and U.S., 2004



Source: Energy and Environmental Analysis, Inc. State Diesel Emission Inspection Programs: Trends and Outcomes. (2004). Retrieved September 15, 2006, from http://www.arb.ca.gov/msprog/hdvip/hdvip.htm#test_facilities

5.1 Federal Manufacturer-Related Enforcement Procedures

Under Title II of the Clean Air Act (40 CFR Parts 85, 86, and 89) the EPA requires that engine manufacturers test vehicles and engines under federal test procedures. Manufacturers are required to verify that vehicle emission control systems are consistent during testing and actual operation (EPA, 2006b). Verification requires detailed information "regarding test programs, engineering evaluations, design specifications, calibrations, and design strategies incorporation for operation both during and outside of the applicable Federal emission test procedure" (Federal Register, 2005, p. 40432).

EPA also inspects "vehicle and engine manufacturing facilities, emission laboratories, dealers of vehicles and mobile engines and suppliers and installers of vehicle and engine parts" (EPA, 2006e). The most common way that EPA detects such violations is by "spot testing vehicles, notifications from the manufacturers or information from a variety of other sources such as state inspection stations" (EPA, 2006b). Manufacturers are also responsible for notifying EPA when "substantial numbers of defects occur in a vehicle's emissions control system." Manufacturers that do not notify EPA of emissions defects in a timely fashion can experience judicial penalties for vehicle sold with a defeat device (EPA, 2006b). Recalling vehicles is another option available to the EPA if vehicles do not meet emissions standards. Finally, EPA has proposed that heavy-duty highway diesel trucks be required to have onboard diagnostic (OBD) systems installed (EPA, 2007a). These systems use a malfunction indicator light on the dashboard to show when the OBD system detects high emissions or other engine malfunction. When there is a malfunction, the light remains illuminated until a services technician clears the OBD system computer or until a "repeated reevaluation by the OBD system fails to detect a reoccurrence of the problem" (EPA, 2007b).

When EPA suspects that a regulated entity is seriously out of compliance, it conducts a civil investigation, which provides a detailed assessment of compliance. Such investigations "may be warranted when an inspection or record review suggests the potential for serious, widespread, and/or continuing civil or criminal violations, from a continuing pattern of citizen complaints, referrals from another agency, or from studies conducted by the regulating agency inferring a potential compliance problem" (EPA, 2006f). The penalty for violating motor vehicle emission requirements can be as much as "$27,500 per violation (per day or per motor vehicle/engine) (EPA, 2006g). Tampering with engines to insert defeat devices may incur a penalty of as much as $2,750 for each vehicle or engine (EPA, 2006g).

5.2 California's Manufacturer-Related Enforcement Procedures

In California, engine manufacturers are required to self-certify engines before sale. Such self-certification ensures that engines have been built to meet California state laws to minimize emissions. In addition, the CARB cooperates with the California Highway Patrol to test heavy-duty trucks for excessive emissions. Inspection and testing procedures apply to any heavy-duty truck traveling through the state, including those registered in other states or other countries. The two main programs CARB runs are the California Heavy-Duty Vehicle Inspection Program (HDVIP) and the Periodic Smoke Inspection Program (PSIP). In HDVIP, field inspectors test emissions of vehicles with a gross vehicular weight over 6,000 pounds at California Highway Patrol weigh stations, fleet facilities, ports, and roadside locations selected randomly (CARB, 2006a). Under Chapter 727 Statutes of 1998, CARB must also conduct the HDVIP and random roadside inspections at California-Mexico border crossings. HDVIP tests include the following:

- **Anti-smoke inspection**: Vehicles are directed to special inspection lanes, where inspectors choke the wheels and ask drivers to depress the accelerator rapidly with the transmission in neutral until they reach maximum speed. The procedure ensures that the vehicle is in proper mechanical condition to prevent excess emissions.

- **RPM recording:** Inspectors record RPM while the vehicle is at idle and at maximum governed speeds.

- **Snap-acceleration test** (smoke opacity test): A smoke sensing meter is placed inside the vehicle's smoke stack and then the driver accelerates with the transmission in neutral. The meter measures the opacity of the smoke emitted. Engines built before

1991 must not exceed 55 percent smoke opacity, and engines built after 1991 must not exceed 40 percent smoke opacity.

- **Visual inspection:** Inspectors check under the vehicle's hood for evidence of tampering and record engine data

Under California's Periodic Smoke Inspection Program (PSIP), owners of all fleets of at least two heavy-duty vehicles based in California must annually perform a snap-acceleration test and inspect for tampering (CARB, 2006b). Engines in the first four model years are exempt; for instance, in 2000, all engines model years 1997 to 2000 would be exempt (CARB, 2006a). Although it lacks the resources to test all engines itself, the CARB randomly checks a representative sample of vehicles' fleet maintenance and inspection records (CARB, 2006a).

Between June 1998 and December 2004, under HDVIP, the CARB performed 116,734 visual inspections and issued 7,724 citations. Of all vehicles tested, seven percent failed, and $1,848,000 penalties were assessed, with $1,457,037 actually collected (Jacobs, 2005a). Penalty funds are used to research clean diesel technology, support the Carl Moyer Program, which funds public or private entities that use clean engines, and support the Smog Check Program (Jacobs, 2005a). In 2006, CARB's HDVIP program conducted 17,585 inspections and found 703 violations, which yielded $205,200 in assessed penalties, of which $199,807 has been collected. According to an expert at CARB, about 70 percent of companies comply with self-certification regulations at some level. The 30 percent that ignore regulations are often large companies that have been in existence for long periods of time and discontinued annual self-certification after years passed in which they were never audited.

5.3 Challenges in Testing Engines for Excessive Emissions

Limitations of technology used to test vehicles for excessive emissions affect federal and state agencies' ability to improve air quality through regulation and enforcement. For instance, none of California's HDVIP programs directly test emissions from the engine. To do so, a chassis dynamometer must be used, which usually requires engine removal. Many engine manufacturers and trucking companies are responsible for self-policing because of this high cost. Opacity data can be converted to emissions, but the conversion is not straightforward (CARB, 2006a).

Even if cost were not a barrier to testing, the effectiveness of dynamometers has been called into question. In a study using chassis dynamometer data, Clark et al. (2002) found that vehicle class and weight are among the factors with the greatest impact on emissions. However, emissions regulations apply to engines, not vehicle class or the type of use of the vehicle, which means that testing and certification procedures could be missing a substantial contributions to emissions (Clark et al., 2002). Clark et al.'s findings also call into question the effectiveness of chassis dynamometer tests. They found that depending on how chassis dynamometer tests were run, PM emissions readings and NO_x readings varied by factors of 15 and 3 respectively (Clark et al., 2002). This finding is significant since chassis dynamometer testing is the method used to develop the heavy-duty diesel emissions inventory. Another problem is that the timing of in-cylinder fuel injection during engine certification tests often is not the same as the timing during actual operation (Clark et al., 2002). According to Clark et al., such timing variations of fuel injection in electronically controlled diesel engines "present the single greatest obstacle to present-day mobile source emissions inventory prediction" (Clark et al., 2002, p. 94).

In addition to these technological challenges, there are questions about the accuracy of opacity tests. In a study of the emissions benefits of smoke opacity tests, McCormick et al. (2003) tested 26 vehicles of various model years using both smoke opacity tests and chassis dynamometer tests. They found that smoke opacity tests poorly predicted PM emissions during driving. Instead, peak carbon monoxide measurements during snap-acceleration tests more accurately predicted PM emissions (McCormick et al., 2003).

One other challenge at the state level is the need for data sufficient to evaluate and improve the effectiveness of emissions inspection and enforcement programs. An analysis of emission inspections programs in the U.S. and Canada by the Energy and Environmental Analysis, Inc. found that while all states collect data on emissions inspection, only Arizona, California, and Colorado have data that is organized and complete enough to be analyzed (Energy and Environmental Analysis, 2004). Using such data could help increase effectiveness of emissions inspection programs.

5.4 Enforcement of Fuel-Related Regulations

Under Title II of the Clean Air Act (40 C.F.R. §79 and 80), EPA enforces fuel provisions to reduce emissions from vehicles including heavy-duty trucks. The provisions apply to "refiners, importers, distributors, carriers, oxygenate blenders, retailers and wholesale-purchaser-consumers (fleet operators with their own dispensing pumps)" (EPA, 2006b). EPA monitors compliance through environmental audits, inspections, and record-keeping and reporting requirements. If EPA detects violations of the regulations, it "may seek civil penalties or injunctive relief" through the "federal district court or through administrative actions" (EPA, 2006b).

CARB also has a Fuels Enforcement Program through which it monitors the composition of motor vehicle fuels including diesel. To check for compliance, CARB inspectors conduct inspections at production, transport, and dispensing facilities. At the Mobile Fuels Laboratory, CARB evaluates the sulfur, aromatic hydrocarbon, and polynuclear aromatic hydrocarbon content of diesel fuel. When inspectors detect a violation, they conduct an investigation of field data and company records and data to determine the cause and magnitude of the violation (CARB, 2004b). The CARB sampled 230,276,000 gallons of diesel fuel in 2006, found 519 violations. The CARB also inspects diesel fuel at refueling stations (truck stops) to ensure that the fuel being sold in California meets the CARB specifications.

As mentioned above, EPA initiated implementation of a new ULSD fuel requirement in 2006. In the 2005 Highway Diesel Fuel Pre-Compliance Reports, the EPA stated that refiners were prepared to comply with the new sulfur standard by the June 2006 deadline and would be ready to provide ULSD fuel nationwide. The EPA estimated that 90 percent of all diesel fuel produced in 2005 would be low in sulfur (EPA, 2006i). However, EPA is continuing to experience difficulties implementing its new ultra-low sulfur diesel requirements due to industry stakeholder concerns. The rule was promulgated in 2001, which provided industry with six to ten years to develop engines and fuels that meet the new standards (GAO, 2006). However, trucking companies worry that the new technology required under the 2007 rule will be too costly and will decrease fuel efficiency to a greater extent than EPA has predicted (GAO, 2006). The GAO found that nine out of ten trucking companies they contacted admitted that they would stock up on older trucks again before the new rule is implemented, which could again disrupt markets and delay emissions reductions (GAO, 2006).

6.0 CURRENT VOLUNTARY AND INCENTIVE BASED APPROACHES TO REDUCE DIESEL EMISSIONS

This section describes incentive-based approaches to reducing emissions federally and in California.

6.1 Federal Programs

As discussed above, for decades, states have run in-use emissions testing programs in the absence of a federal requirement. A federal semi-voluntary in-use testing program was been introduced as a result of negotiations between EPA and industry stakeholders. After EPA set the 2004 and 2007 Heavy-Duty Diesel Motor Vehicle Engines Rules, the Engine Manufacturers Association (EMA) and several manufacturers challenged the rules regarding emissions and not-to-exceed standards. After negotiations among EPA, CARB, EMA, and EMA's member companies, the parties reached a settlement agreement that established a manufacturer-run, in-use emissions testing program (EPA, 2005). Manufacturers will test fleet or customer-owned, in-use trucks starting with model year 2007 using the 2007 PM and NO_x standards. Emissions testing protocols for model years 2005 and 2006 will be piloted as well. Manufacturers will use portable emission measurement systems (PEMS), which are installed onboard the vehicle to measure emissions of HC, CO, NO_x and PM under realistic driving conditions.

EPA hopes that the program will increase manufacturers' ability to address engine problems and encourage them to design cleaner and more durable engines. Usually, in order to test engine emissions, engines have to be removed from the truck and tested in a laboratory using an engine dynamometer. This program may improve emissions compliance by testing vehicles in-use and under conditions much closer to those on the road. When manufacturers find engines that do not comply with regulations, they will test more engines to determine "if further action is necessary" and EPA will use the data "to make independent evaluations about the possible need to pursue further actions" (EPA, 2005). Manufacturers will conduct and pay for the emissions testing under the oversight of the EPA (DieselNet, 2005; EPA, 2005). The CARB plans to adopt a similar testing program (EPA, 2005).

The EPA has also established the National Clean Diesel Campaign to decrease emissions from diesel engines nationwide (EPA, 2006c). The campaign is designed to help implement the 2007 Heavy-Duty Highway Rule and promote new cost-effective strategies, such as retrofitting engines, repairing engines, reducing idling, and using cleaner fuels. As part of this program, the Voluntary Diesel Retrofit Program Verification Process has been created to evaluate the emissions reductions of retrofit technologies and help engine manufacturers determine which technology is best for their product (EPA, 2006j).

Under the National Clean Diesel Campaign, the SmartWay Transport Partnership partners industry with the EPA to “address greenhouse gas emissions, fuel consumption, criteria pollutants” and operating costs associated with ground freight transportation operations. By 2012, EPA hopes that the partnership will help “eliminate 33 to 66 million metric tons of CO_2 emissions per year” and as many as 200,000 tons of NO_x emissions annually (EPA, 2004, p. 1). Participating companies “commit to integrate innovative cost saving strategies into their fleet operations,” such as idling reduction, improved freight logistics, automatic tires, inflation systems, driver training, advanced lubricants, and advanced power train technologies. The hope is that the companies will reduce operating costs while contributing to improved air quality. Partners must measure environmental performance using the SmartWay Transport Fleet Logistics Energy and Environmental Tracking Performance Model and “commit to improve that performance within three years” (EPA, 2004, p. 2). As an incentive for participation, EPA provides participating companies with “benefits and services that include fleet management tools, technical support, information, public recognition, and, for exceptional environmental performers, use of the SmartWay Transport Partner logo” (EPA, 2007c). Another incentive is cost savings – the SmartWay program works with states, banks, and relevant organizations to create financing options that allow partners to save fuel and cut costs.

One program within SmartWay is the National Transportation Idle-Free Corridors project, which aims to eliminate unnecessary idling of trucks. States and non-profits can receive grants from this program that allow them to demonstrate truck idling technologies. States that have received the funds include Arkansas, California, Illinois, Indiana, Massachusetts, Missouri, New York, North Carolina, Oregon, and Washington. According to EPA, these grants “leverage more than $2 for every federal dollar invested,” and demand for funding has been high (EPA, 2006k).

6.2 California Programs

The California’s Council on Diesel Education and Technology (CCDET) is a collaborative training effort run by community colleges, government, and industry in order to improve compliance with the Heavy-Duty Vehicle Inspection Program and the Periodic Smoke Inspection Program. Through the program, diesel repair facility technicians and fleet owners can take affordable one-day courses at selected California community colleges in which they learn about HDVIP and PSIP (CARB, 2005b). Participants learn how to properly administer the snap-acceleration test required by both HDVIP and PSIP and gain skills in troubleshooting and repair (CARB, 2005b).

The Carl Moyer Memorial Air Quality Standards Program was created in 1998 to help improve near-term reductions in NO_x emissions from heavy-duty engines in California. The program funds help California meet air quality standards under the State Implementation Plan. Local districts can fund efforts on behalf of public or private groups to use “cleaner-than-required engines and/or equipment” (CARB, 2003). In the first three years of the program, there was an overwhelming demand for funding, and projects that were funded contributed to a decrease of 11 tons of NO_x emissions per day.

7.0 CHALLENGES IN REGULATION AND ENFORCEMENT

7.1 Diesel Defeat Devices

In 1998, the EPA lowered standards for NO_x emissions in 2004 to 2.5 grams, which gave engine manufacturers time to gradually producer cleaner engines (GAO, 2004). However, between 1987 and 1998, EPA found that rather than produce cleaner engines, manufacturers had sold 1.3 million engines that contained illegal software to mask emissions by altering the timing of fuel injection. Known as "defeat devices," the software increases fuel efficiency but also increases NO_x emissions two to three-fold; however, the software hides these excess emissions during testing procedures (GAO, 2004; U.S. Department of Justice, 1998). The sale of these engines contributed to an excess of 15,748,000 tons of NO_x emissions (GAO, 2004) and over the life of the vehicles the devices "would cause 2,500 premature deaths, 5,000 hospitalizations, and cost $6 to $21 billion dollars in public health expenses" (American Lung Association, 2004).

In 1998, the U.S. Justice Department sued Mack Trucks Inc., Caterpillar, Inc., Cummins Engine Company, Detroit Diesel Corporation, Navistar International Transportation Corporation, Renault Vehicules Industriels, s.a., and Volvo Truck Corporation for installing illegal defeat devices. The suit requested that the court prohibit the companies' sales of engines with defeat devices, required that the companies recall and fix vehicles with the devices that were in use at the time, and ordered the companies to take action to make up for the health and environmental impacts due to the defeat devices.

Later in 1998, the EPA announced an $83.4 million penalty against these companies; it was the "largest civil penalty ever for violation of environmental law" (EPA, 2006h). In the resulting consent decrees, besides the monetary penalty, engine manufacturers were required to devote $109.5 million to research and programs that would decrease NO_x emissions (GAO, 2004). Manufacturers were also required to spend at least $850 million to develop engines that produce no more than 2.5 grams of NO_x emissions per unit of work by October 1, 2002, 15 months before the original deadline for new emissions standards. To maximize compliance with this accelerated schedule, EPA allowed manufacturers to continue to sell the old engines until October 2002. They could only continue to sell those engines past the deadline if they paid nonconformance penalties, if they sold at least as many clean engines before then, or if they reduced emissions in other areas using "emissions averaging, banking, and trading" (GAO, 2004, p. 13).

As mentioned, engine manufacturers that implemented the illegal devices agreed in consent decrees that they would "produce significantly cleaner engines by October 1, 2002" – fifteen months ahead of the original deadline – in order to make up for the environmental damage caused by the defeat devices (GAO, 2006, p. 12). However, rather than work on developing technology to meet the deadline, several large trucking companies reportedly bought more 2002 model engines out of the fear that the new engines would be "costly and unreliable" (GAO, 2004). In order to meet the increased demand for 2002 model engines, engine manufacturers increased production, but when demand decreased, they lost profits and had to lay off workers.

In California, an agreement was also reached with engine manufacturers: when vehicles were up for an engine rebuild, manufacturers of faulty engines, including Caterpillar, Cummins, Detroit

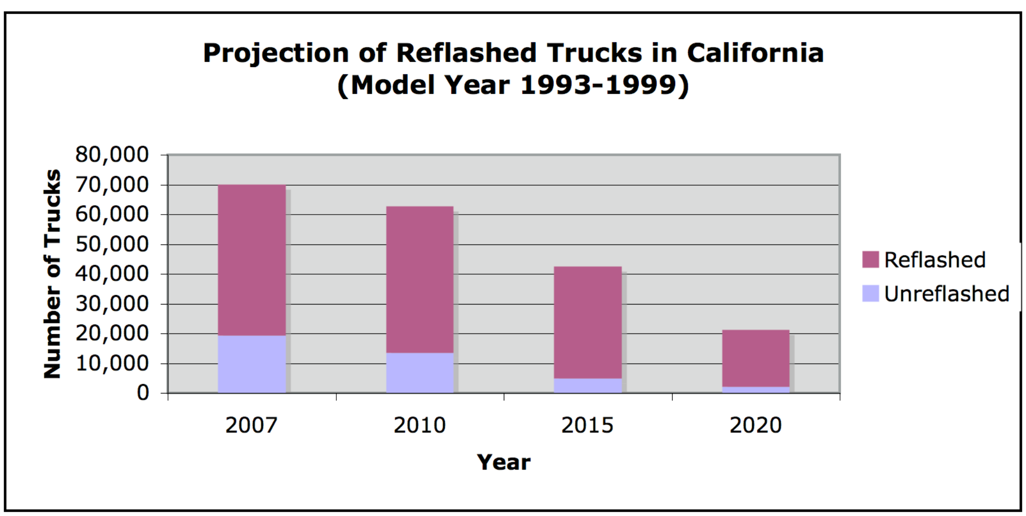
Diesel defeat devices (CARB, 2007a). These regulations apply to approximately 300,000 to 400,000 non-California based vehicles that drive through California and to the 58,000 trucks licensed in California (Thompson, 2006). In 2004, the CARB created a Software Upgrade Voluntary Program Coordination Group to track the progress of the voluntary program with the help of "environmental representatives, dealers, and other stakeholders" (CARB, 2007a).

In 2004, the CARB agreed on a voluntary plan in which engine manufacturers would attain 35 percent compliance by the fall of 2004 and full compliance by 2008. One challenge with this approach to renovating the engines is that heavy-duty diesel truck engines are very durable, so they will not need to have their engines rebuilt for many years. By the September 7, 2004 deadline, only 15 percent of vehicles licensed in California had complied by the fall deadline. This was 20 percent lower than the target compliance of 35 percent (CARB, 2007a). The low rate of compliance has serious repercussions: CARB estimates that defeat devices are responsible for 30 to 40 tons of daily NO_x emissions statewide (American Lung Association, 2004).

As a result, CARB determined that mandatory regulations were necessary. In 2005, CARB set regulations requiring owners of all 1993 to1998 truck models to install low NO_x software. In 2006, Caterpillar, Cummins, Mack/Renault, and Volvo alleged that the CARB has no authority to adopt such regulations. In January of 2007, the Sacramento County Court ruling confirmed that the Low NOx Software Upgrade Regulation was invalid. Nevertheless, engine manufacturers are still required to install low NO_x software when their engines are rebuilt (CARB, 2007b).

In California, it was estimated in 2007 that there were approximately 396,050 medium-heavy and heavy-duty diesel trucks in operation. Of these, 70,075 need to be reflashed, meaning that they need to have the correct low NO_x software installed. However, 28 percent have yet to be reflashed. The figure below shows CARB's projection for the number of trucks to be reflashed through 2020 among all trucks that can be reflashed. By 2020, CARB expects that about 2,000, or 10 percent, will still need to be reflashed.

Figure 2. Project of Reflashed Trucks in California (CARB, 2007)



8.0 TRUCK IDLING REGULATION AND ENFORCEMENT

In addition to the technical factors affecting emissions, such as engine design, maintenance, and fuel, patterns of truck operation also affect diesel emissions. Specifically, the truck idling increases the likelihood that community members will experience the negative health effects due to emissions from heavy-duty diesel engine trucks. In this section, we discuss the problems associated with excessive idling, the existing regulations to curtail idling, and the enforcement procedures and barriers to compliance and enforcement.

Throughout the duration of their trucking, most truck drivers idle their engines during rest periods in order to control the temperature of the cab, run electrical appliances, to keep the engine heated, or while awaiting shipment drop off or pick up (U.S. Federal Highway Administration, 2005). Ports are one example of an area with frequent truck idling and high levels of emissions because of the heavy volume of trucks passing through each day. Particularly because shipments are not always timed perfectly with the arrival of trucks, ports are a hot spot for truck idling. According to a report by the U.S. Federal Highway Administration (FHWA), most trucks idle for approximately six hours each night and between 1,800 and 2,400 hours per year (FHWA, 2005; Turchetta, 2005). Each hour a long-haul truck idles, it burns about 3.8 liters of fuel, and overall, idling trucks waste up to 3.78 billion liters of fuel each year (Turchetta, 2005). This wasted fuel yields 163,000 metric tons of NO_x, 4,535 metric tons of PM, and 9.98 million metric tons of CO_2 every year (Turchetta, 2005).

In a national survey of line-haul truck drivers, Lutsey et al. found that engines idled for 34 percent of total run time on average and that each truck idled approximately 1,700 hours each year (Lutsey et al., 2004). They also found that the frequency of idling varies depending on the season, the owner of the truck, company idling strategies, and the experience of the driver (Lutsey et al., 2004). Climate control was found to be the main reason for truck idling, followed by powering accessories, "avoiding start-up problems, drowning out other noise, and reducing engine maintenance" (Lutsey et al., 2004, p. 1880). On average, owner-operators idle less, possibly because of their "better understanding and greater responsiveness to the higher operating costs associated with idling" (Lutsey et al., 2004, p. 34). Drivers for companies that made no efforts to reduce idling, idled for roughly an additional hour each day, compared to drivers whose companies had a formal program or strategy to reduce idling (Lutsey et al., 2004). In addition, drivers over age 50 and with over 30 years of professional driving experience idled less, which could be due to their "decreased overall workload in older age … or their increased sensitivity to idling-related sleep discomfort" (Lutsey et al., 2004, p. 36). Lutsey et al. determined that the average truck idles about $2,000 for each year's worth of fuel during idling; however, an estimated 25 percent of drivers used over $3,000 worth, and 10 percent used over $4,500 worth (Lutsey et al., 2004).

To address excessive idling of trucks, California has passed regulations (Section 2485 – Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling) effective February 1st, 2005, which prohibit drivers of any diesel-fueled commercial vehicles with a gross vehicular weight ratings over 10,000 pounds operating in California from idling the vehicle's primary diesel engine for more than five minutes, with some exceptions[1]. In addition, truck drivers may not idle a diesel-fueled auxiliary power system for over five minutes to “power a heater, air conditioner, or ancillary equipment on the vehicle during sleeping or resting in a sleeper berth for greater than 5.0 minutes at any location within 100 feet of a restricted area” (CARB, 2006b; CARB, 2005a). The EPA has no such idling regulations at the federal level. In 2006, CARB conducted 1990 idling inspections and issued 90 citations/notifications of violation. There is currently a bill pending (AB 233-Jones) that would increase funding for enforcement of idling regulations as well as CARB’s other enforcement programs.

There are several alternatives to idling that use less fuel and could decrease emissions. Auxiliary Power Units (APUs) are small diesel-powered generators installed on trucks that can power air conditioning, heat, or appliances (Turchetta, 2005). Most APUs can provide up to 8 or 10 hours of power (Turchetta, 2005). At truck stops, drivers can also utilize “shore power” by running an extension cord from a source of electricity to the truck to maintain cabin temperature and power appliances; however, using shore power requires engine modification (Turchetta, 2005). Another method is truck stop electrification (TSE) or electrified parking spaces that allow drivers to pull into a parking spot and insert a plastic template through the window that is connected to overhead truss with electrical power (Turchetta, 2005).

9.0 THE NORTH AMERICAN FREE TRADE AGREEMENT

In addition to truck travel within the U.S., truck traffic between the U.S. and Mexico pose significant challenge to reducing emissions. Since the initiation of the North American Free Trade Agreement in 1994, trade between Mexico and the U.S. has increased significantly. Trucks are one of the key freight carriers delivering goods across the U.S.-Mexico border. California is home to the second largest border crossing at Tijuana-Otay Mesa (near San Diego) (Jacobs, 2005b). Each day, about 3,500 trucks enter California from Mexico (Jacobs, 2005b). The U.S. has held a moratorium on issuing permits to companies seeking to operate heavy-duty diesel trucks in the U.S. since 1982 (Putnam, 2003). The moratorium limits non-licensed Mexican trucks traveling in the U.S. to a 20-mile commercial zone near the border (Jacobs, 2005b).

When NAFTA was introduced, the U.S. agreed to phase out the moratorium by December 18, 1995 (Putnam, 2003). The deadline passed without any change in U.S. policy, so Mexico filed an arbitration action, and the arbitral panel found that the U.S. was in breach of its obligations under NAFTA (Putnam, 2003). President Bush announced that he would lift the moratorium as soon as the Federal Motor Carrier Safety Administration developed new regulations granting Mexican motor carriers operating authority in the US (Jacobs, 2005b). However, when the FMCSA prepared the regulations, “a coalition of U.S.-based environmental, consumer, and trucking organizations filed a suit in federal court” claiming that the “Department of Transportation had failed to comply with two federal environmental statutes: the National Environmental Policy Act of 1969 (NEPA) and the Clean Air Act” (Putnam, 2003, p. 1288). The plaintiffs claimed that allowing Mexican trucks into the U.S. would cause a significant increase in air pollution because

[1] CARB allows trucks to idle due to traffic conditions, when queuing while at least 100 feet from homes and schools, in order to check for safe operating conditions, or for mandatory tests, repairs, or diagnostics.

1) Mexico's truck fleet is older, 2) Mexico lacks new fuel standards that the EPA has set for the next ten years, and 3) Mexican companies may not be required to remove defeat devices as U.S. manufacturers must (Public Citizen, 2002). In 2003, the U.S. Court of Appeals ruled that before opening its borders to Mexican trucks, the U.S. government must conduct a study of the extensive environmental impact of the trucks (Public Citizen, 2002).

In 2004, the Supreme Court held that U.S. environmental laws do not require an evaluation of the environmental effects of operations of Mexican domiciled trucks in the U.S. (Supreme Court of the United States, 2003). As a result, the moratorium could be lifted once FMCSA promulgates final regulations (CARB, 2006a). Carrying on the concerns of the plaintiffs, members of Congress introduced two bills (S. 2842 – Boxer/Feinstein/Jeffords and HR. 5314 – Filner/Millender-McDonald, Carson and Sandlin) in 2004 to require the Federal Motor Carrier Safety Administration to "withhold access of any Mexican heavy duty diesel powered vehicle unless it meets U.S.EPA emissions standards for the year model of the vehicle's engine" (Jacobs, 2005b, p. 3). If these bills had been passed into law, no additional Mexican trucks would be allowed in the U.S. based on current Mexican emissions standards (Jacobs, 2005b).

California did successfully sign into law a bill (AB 1009, Pavley) which requires – "to the extent permissible under federal law" – that heavy-duty commercial trucks entering California must "possess evidence that its engine met the federal (EPA) emissions standards for that model year" (U.S. Department of Justice, 1998). Under the statute, CARB must consult with the California Highway Patrol to develop and implement an inspection protocol for trucks entering California from Mexico to ensure that they meet emissions standards (Jacobs, 2005b). At the federal level, there has been no date set for allowing commercial vehicle travel from Mexico to the U.S. From a preliminary analysis of Mexican fleet characteristics, CARB determined that the regulation requirements under AB 1009 would possibly prevent emissions increases of 2.9 tons/day of NO_x and 0.12 tons/day of PM across the state (Thompson, 2006).

Nationwide, most experts predict that an end to the moratorium would likely lead to an influx of Mexican trucks on U.S. highways because of the significantly lower service costs of Mexican trucks. It is estimated that there will be approximately 30,000 extra truck crossings each day into the U.S., if NAFTA provisions are implemented (U.S. Department of Justice, 1998). The age of the Mexico fleet is of concern: 66 percent of Mexican trucks are models that are not fully electronically converted, which means that they lack the electronic fuel injection and computer controls necessary to reduce emissions (Jacobs, 2005b). In addition, a quarter of Mexican trucks are pre-1980 models, which are known to emit high levels of NO_x and PM (Jacobs, 2005a). Mexico did not set standards for its heavy-duty diesel vehicles until 1994, when its standards were aligned with those of the U.S. EPA. However, it did not update its standards to match U.S. EPA's tighter restrictions on NO_x and PM emissions for post-2003 models (see Table 2) (CARB, 2006a). Thus, even though Mexico's diesel engine emissions standards are the same as the U.S. standards for 1994 to 2003 models, the majority of its trucks do not meet U.S. standards and will continue to emit significantly higher levels of air pollutants than are allowed in the U.S. (Jacobs, 2005b). In addition, access to cheaper Mexico-domiciled trucks could reduce freight costs and increase demand for trucking services and in turn increase emissions (Putnam, 2003).

In a study using portable emissions measurement systems and tapered element oscillating micro-balance equipment, Zietsman et al. (2006) found that at the El Paso-Ciudad Juarez border, on average, at least 60 percent of trucks were idling or creep idling while crossing the border. Ang-Olson and Cowart (2002) found that cross-border freight accounts for three to 11 percent of NO_x emissions and five to 16 percent of $PM_{2.5}$ emissions of all mobile sources in the U.S.-Mexico corridor region.

In California, CARB estimates that once the border opens to Mexican commercial trucks, the two border crossings will experience an increase from 3,500 crossings per day to between 12,250 and 17,500 per day (CARB, 2006a). The increased traffic could create an additional 50 tons of smog-forming pollutants each day (CARB, 2006a). Since 1999, California has conducted its HDVIP program at the two border crossings and in the border area; since then, the opacity test failure rate has been consistently higher at the border region than in the rest of the state, which is likely due to the older age of Mexico's truck fleets (CARB, 2006a). Based on anecdotal reports, CARB expects that the majority of new truck trips will be to and from the Ports of Long Beach and Los Angeles.

According to CARB, other possible strategies include expanding the Tijuana Inspection and Maintenance Program into urban areas of Baja California to cover all vehicles, continuing enforcement of the Heavy Duty Vehicle Inspection Program in the border region, and continuing "aggressive collections of delinquent HDVIP citations at the Mexican border and statewide" (Jacobs, 2005b, p. 4).

While Mexico has not altered its emissions regulations, in 2005 it announced a demonstration project that would retrofit diesel trucks based in Tijuana, Mexico with oxidation catalysts and particulate filters used in combination with ultra-low-sulfur diesel fuel (U.S. Department of State, 2005). The project is part of the Security and Prosperity Partnership of North America, which aims to "address the threat of terrorism and enhance North American security, competitiveness and quality of life" (U.S. Department of State, 2005). In addition, Mexico has announced that it plans to require the use of ultra-low sulfur diesel in border regions as of 2007, and it hopes to extend the regulation to the whole country by 2009.

Table 2 Comparison of U.S. and Mexico Heavy-Duty Diesel Vehicle Emission Standards (in grams per brake horsepower-hour)

Reproduced from Jacobs, P.E. (2005). NAFTA/Mexican truck emissions overview. California Air Resources Board. Retrieved October 1, 2006, from www.arb.ca.gov/msprog/hdvip/ bip/naftamextrk.pdf

	Hydrocarbons		Carbon Monoxide		Nitrogen Oxide		Particulate Matter	
Year	U.S.	Mexico	U.S.	Mexico	U.S.	Mexico	U.S.	Mexico
1974-78[a]	-	-	40.0	-	-	-	-	-
1979-83[b]	1.5	-	25.0	-	-	-	-	-
1984-84	1.3	-	15.5	-	10.7	-	-	-
1988-89	1.3	-	15.5	-	10.7	-	0.6	-
1990	1.3	-	15.5	-	6.0	-	0.6	-
1991-93	1.3	-	15.5	-	5.0	-	0.25	-
1994-97	1.3	1.3	15.5	15.5	5.0	5.0	0.1	0.1
1998-2003	1.3	1.3	15.5	15.5	4.0	4.0	0.1	0.1
2004-2006[c,d,e]	0.5	1.3	15.5	15.5	2.0	4.0	0.1	0.1
2007+	0.14	1.3	15.5	15.5	0.2	4.0	0.01	0.1

[a] U.S. had combined HC + NO_x standard of 16 g/bhp-hr
[b] U.S. had combined HC + NO_x standard of 10 g/bhp-hr
[c] Under a consent decree with U.S. EPA, engine makers implemented the 2004 standards in October 2002
[d] Standards allow the option of 2.4 g/bhp-hr NMHC + NOx, or 2.5 g/bph-hr NMHC + NOx and 0.5 NMHC
[e] Assumes no future change in Mexican emission standards

10.0 CONCLUSIONS

In recent decades, the transportation of goods using heavy-duty diesel engine trucks has made a significant contribution to economic growth in the U.S. However, at the same time, there has been increasing recognition of the negative externalities associated with gaseous and particulate emissions from such trucks. One of the most significant challenges to decreasing emissions from diesel engine trucks has been the influence of industry stakeholders. Through their collective efforts to block new regulations, place pressure on the EPA to delay deadlines for new regulations, and purposeful evasion of laws and deadlines, the industry can essentially set the agenda for EPA's air quality programs. Even though the EPA has successfully enforced violations of emissions laws and collected substantial monetary penalties from violators, their ability to effectively improve air quality is significantly hampered by industry pressure throughout the regulation process. As a result, some of the largest programs involving emissions measurement are voluntary and require industry cooperation and little to no enforcement.

Even California, the state with the most stringent regulations on diesel emissions from trucks, faces serious threats to enforcement due to the lack of enforcement at their borders. On two of its borders, California faces states with less stringent regulations and a lower enforcement rate, increasing the likelihood of violations of trucks from other states. At California's southern border, trucks enter from Mexico, which also has lower emissions standards, posing a serious enforcement challenge to CARB.

Certain populations, such as low-income and ethnic minority groups, have suffered the greatest burden of ill health due to diesel emissions. Inadequate federal and state level regulation and enforcement of diesel engine emissions is reflected in the increasing number of lawsuits related to cancer or respiratory problems due to diesel emissions since the 1980. A recent law review article concluded that "diesel exhaust litigation is gaining momentum within the plaintiff's bar and will pose an increasing threat to industries reliant upon diesel power, such as motor carriers" and companies should "analyze their assets for responding to these risks" (Lewis and Setliff, 2004, p. 159).

However, litigation is only one answer to the inadequate regulation and enforcement. Communities themselves have worked from the grassroots level to protect and improve health and environmental effects of diesel emissions and other harmful actions when the government fails to provide adequate protection. In particular, such activists, like those in West Oakland, focus on minority and low-income populations. The efforts of these activists have resulted in improved enforcement at the local level, for instance, as in West Oakland. In addition, the environmental justice movement, which started in the 1980's, has contributed to the development of "community-based participatory research", which engages scientists with community members to measure the ill health and environmental effects experienced by disadvantaged community members. The products of such collaboration are published for other residents, the media, and policymakers in the hopes that sustainable solutions are placed on the public agenda (Shepard et al., 2002).

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APPENDIX E

Expert Interviews: Pavement, Safety, Security, Air Quality, and Technology

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1: PROJECT INTRODUCTION AND REPORT ORGANIZATION

This appendix documents the stakeholder interviews summarized in the executive summary of this report. Researchers with Innovative Mobility Research (IMR) at California Partners for Advanced Transit and Highways (PATH) conducted 20 stakeholder interviews with representatives from public and private organizations, including federal, state, and local commercial vehicle regulatory and enforcement agencies, trucking companies, and technology vendors. These interviews were conducted between April and August 2006.

2: STAKEHOLDER OUTREACH/EXPERT INTERVIEWS

2.1 Interview 1

The first stakeholder/expert interview was conducted with a Caltrans researcher who has ten years of research experience in goods movement. The expert identified several weaknesses in the current commercial vehicle screening and enforcement process in California. The expert's position as a researcher allows him to have access to data on the estimated and verified numbers of trucks being inspected in California each year. The expert stated that too many trucks use the highways and roadways in the state and a lack of enforcement officers makes manual or traditional commercial vehicle enforcement obsolete. The expert also identified a lack of data on the number of overweight trucks as a major weakness of the current screening system. The expert believes that overall enforcement is a problem; however, before possible solutions can be tested, it is necessary for researchers to gain a better understanding of the distribution, scope and severity of the problems associated with the current system.

The expert believes that these weaknesses should first be addressed by establishing a system to collect data on overweight trucks, including using mobile VWS systems to collect data at various locations (e.g., freeways, bridges, near ports, on rural highways and non-truck routes).

In addition, the expert believes that all trucks should be mandated to register and participate in the PrePass program. According to the expert, this would allow for trucks to be tracked in a more efficient manner. The expert believes that the key to making this idea work is to link the transponder with the vehicle since the current system can be abused by truckers trading transponders with other truckers. This can be accomplished by linking the transponder to the Vehicle Identification Number (VIN). The current PrePass system has approximately a 10 - 15% bypass rate. The expert estimates that mandating all trucks to carry the PrePass transponder would increase the bypass rate to 80%. The expert stated that mandating participation in the PrePass program may require enabling legislation.

Another possible solution to these weaknesses, identified by the expert, is to make the ports liable for overweight trucks instead of the truck owners, who are usually the drivers. The expert believes that this strategy would encourage port operators to weigh trucks before they leave the ports, increase compliance and safety, and reduce pavement and structural damage.

The expert was able to identify specific locations where commercial vehicle enforcement is a problem. For example, the bridge on State Route 47 carries an estimated 1,000 trucks per day. According to the expert, sample data from this area suggests that many of these trucks are 100,000lbs, which is overweight for the bridge. If traditional enforcement was used in this area an officer could stop approximately one truck per hour and eight trucks per day, with no way of knowing if the truck was actually overweight until the truck was stopped and weighed. The expert also outlined safety concerns associated with stopping a truck in this area. The expert believes that this bridge is a prime location to deploy and test a mobile VWS system designed to collect data and gain an understanding of the scope of the problem. The goal of deploying a system in this area would be to increase productivity and efficiency (e.g., enforcement), and improve safety.

The expert believes that the “experts” in charge of the current commercial vehicle enforcement process in California do not have enough data to understand the effectiveness of the current process. According to the expert, current assumptions are based on simulation models, which the expert believes are flawed. The expert stressed the importance of collecting data to gain a broader understanding of the current system and the problems associated with it. For example, the expert stated that it is common for truckers to avoid weigh stations by using non-truck routes. However, there is no data that actually measures this problem, so we do not have a true understanding of its severity.

The specific agency that the expert works for is interested in VWS to increase safety, reduce pavement and structural damage and would like to create a sustainable WIM system for the state. According to the expert, their goal is to create a screening system that is better, faster and cheaper than the current system.

When asked about the use of different applications for VWS technologies, the expert was able to provide significant feedback. The expert’s organization is interested in using the technology to identify overweight vehicles; they would also like to mandate all trucks to carry DSRC devices to monitor credentials, use imaging technology to identify gross polluters in urban areas and use and combine systems (e.g., gamma ray detectors and heat seeking devices) to improve homeland security and track hazardous materials. The expert supports these VWS applications in all locations (e.g., truck-only routes, alternative routes used to avoid inspection stations, rural roads, urban high-volume roads, ports and bridges).

The expert stated that mobile VWS sites are more effective than fixed sites. The expert supports the use of mobile sites in all locations (e.g., on bridges, rural roads, freeways, near ports and to track trucks using non-truck routes). He believes that deploying mobile sites would give enforcement agencies an upper hand in catching violators. He feels that the current fixed sites are not good data points because truckers already know about them and how to avoid them.

The expert supports the use of semi-automated systems, which use a VWS system combined with an officer. He believes this would be an effective tool in all locations. The expert stated that using a fully automated system is a significant financial investment and does not know if the state is ready to move in that direction yet.

The expert and his management support standardizing the location, placement and color of commercial vehicle license plates as well as mandating that all DOT numbers are placed in a location where they are clearly visible.

The expert identified government agencies charged with the oversight of commercial vehicle enforcement as the major source of support for the use of VWS systems. He identified truckers and commercial vehicle operators, as well as law enforcement, as the major opposition to the use of these systems. He feels the cost of DSRC devices may deter truckers and CVOs. In addition, the expert believes that law enforcement may oppose this technology based on fears of losing their jobs if a fully automated system was deployed.

The expert is interested in participating on the advisory board.

2.2 Interview 2

The second stakeholder/expert interview was conducted with an expert who has over 26 years of experience with Mettler Toledo, Inc. This company installs and maintains commercial vehicle weigh station equipment in the U.S. and also in the U.K. The expert was able to provide researchers with Mettler Toledo's organizational perspective on current commercial vehicle inspection processes. According to the expert, several weakness/problems exist with current inspection processes in California, including the number of trucks on the road, which overwhelm the weigh stations and cause weigh station operators to close facilities so trucks do not queue in the roadway and cause a roadway hazard or safety concern. Other problems include truckers knowing where the current weigh stations are located and avoiding these facilities, and that there is no system capable of tracking all of the trucks currently on the nation's roadways.

The expert and his company believe that in order to address these problems, commercial vehicle enforcement facilities (CVEF) should be built, more officers should be assigned to commercial vehicle enforcement, more mobile WIM units should be deployed on rural roads and around ports and port operators should be held accountable for overweight trucks leaving their facilities. The expert provided researchers with problem locations on the 710 Freeway, which is located near the Port of Long Beach. According to the expert, this is a problem location because overweight trucks travel through neighborhoods and on rural routes to avoid the weigh stations. For example, the expert believes that many overweight trucks never enter the 710 and 405 freeways, but instead drive on an access road adjacent to the 710 Freeway. The expert believes that the areas surrounding the 710 Freeway are prime locations for the use of mobile WIM units.

The expert and his company believe that the PrePass program is underutilized and money should be spent to increase mobile weight sensors.

The expert and his company support the use of VWS technologies to identify and track overweight vehicles; the use of DSRC devices to electronically check truck credentials and safety records; and the use of gamma ray detectors and heat seeking devices for homeland security applications, including tracking illicit cargo, potential weapons and human trafficking. The expert and his company support the use of these technologies in any and all locations (e.g., truck-only routes, alternative routes used to avoid inspection stations, rural roads, urban high-volume roads, ports and bridges). This company is not involved with emissions monitoring and the expert was unfamiliar with this technology.

The expert and his company support the use of both mobile and fixed VWS sites. The expert believes that it is more cost-effective to deploy mobile units, which cost approximately $200,000 to $300,000 to buy, compared to the millions of dollars it costs to build a fixed site.

The expert's employer currently operates a system that uses weight sensors placed in roadways with a wireless connection to an officer's laptop computer. When a violator drives over the sensor, the officer is notified and can intercept the vehicle. The expert does not believe officers will support a fully automated VWS system because the systems can be inaccurate and an officer needs to be present to intercept and weigh the vehicle. The expert believes that wireless systems accompanied with an officer should be deployed in all locations.

The expert believes that a national standard for license plate color, size, font and location should be passed. The expert and his company also advocate for the standardization of the placement of the Department of Transportation (DOT) number.

The expert feels that Homeland Security and other local and state law enforcement agencies will be the biggest supporters of the use of VWS technologies and that truckers and trucking companies will be opposed to this technology.

Unfortunately, the expert's busy work schedule precludes him from serving on the advisory board.

2.3 Interview 3

The third expert/stakeholder interview was conducted with an expert who has worked for Caltrans District 7 for more than seven years and has over 15 years of experience working in goods movement. The expert was able to provide researchers with an organizational perspective on the problems associated with the current commercial vehicle inspection/enforcement system. These problems include maintenance of weigh station scales since they often break, forcing the weigh station to go offline or temporarily close, and the high costs associated with operating and maintaining commercial vehicle enforcement facilities. The expert believes that investing in technology like VWS is the key to addressing these problems.

Furthermore, the expert believes that investing in mobile VWS technologies will cut costs associated with building fixed sites. The expert provided researchers with a problem location on the 710 Freeway. According to the expert, this site is a problem due to its geography. The freeway runs from the Port of Long Beach into downtown Los Angeles with the Los Angeles River on one side. The expert believes that a need exists for a weigh station to be built; however, the geography prohibits the construction of a fixed site. The expert believes that many overweight trucks travel on non-truck routes, through neighborhoods and on rural roads to avoid weigh stations; also, the lack of a site on the 710 allows truckers to continually travel with overweight loads. The expert advocates for the use of a mobile scale on the 710 to address these problems. The expert believes that Caltrans will begin using mobile scales on and around the 710 Freeway in the next two to three years.

The expert supports the use of both mobile and fixed VWS technologies to identify overweight vehicles (e.g., use license plate readers), improve roadway safety (e.g., DSRC devices to check truck credentials), identify emissions violators (e.g., use emissions sensors to identify gross polluters) and to improve homeland security (e.g., use gamma ray detectors to monitor human trafficking, illicit cargo and potential weapons). The expert supports the use of these technologies in all locations (e.g., truck-only routes, alternative routes used to avoid inspection stations, rural roads, urban high-volume roads, ports, bridges and at border crossings).

The expert supports the use of the PrePass program because he believes it saves time and money for both commercial vehicle operators and for commercial vehicle inspection officers. However, he believes that the PrePass program is underutilized.

The expert supports the use of semi-automated VWS sites but believes that due to the increase in truck travel; fully automated systems will have to be deployed in the future. The expert feels that CHP officers will support the use of a fully automated system; however, trucking companies will oppose it.

The expert and his management support the standardization of license plate font, color and placement. The expert stated that DOT numbers are already standardized.

The expert would like to serve on the advisory board but must obtain permission from his supervisor before making any commitment.

2.4 Interview 4

The fourth expert/stakeholder interview was conducted with the Vice President of ULS Express, a company which manages owner-operated commercial vehicles specializing in short hall trucking. The company manages trucks carrying freight from the Port of Long Beach into downtown Los Angeles.

The interview also included two owner-operated truck drivers that use ULS Express to manage their workload and assign work.

The expert was able to provide researchers with his company's perception of problems associated with current commercial vehicle inspection processes in California. The expert identified small owner-operated commercial vehicles, which he calls "fly by night" companies, as a major problem in California. According to the expert, such companies avoid inspection stations by traveling on non-truck routes. Further adding to the problem is that the CHP only inspects larger trucking companies because they keep accurate records and logbooks, and there are hundreds of owner-operated vehicles that never get inspections. According to the expert, these small companies are often made up of a single driver that will often accept cash for hauling a load. According to the expert, many other small companies will report only having a few employees and will insure a few drivers when it actually has more drivers than it insures. These practices enable such small companies to operate at a lower overhead and make it difficult for larger companies to retain drivers.

Furthermore, the expert reports that many of these owner-operated small trucking companies will shut down if they are citied for a violation and reopen under another name. The expert reports that the average lifespan of a typical owner-operated trucking company is approximately 18 months to three years.

The drivers were also able to provide researchers with some problems that they have encountered in their day-to-day work experiences. According to the drivers, several companies want to pay them in cash to carry loads, assign loads that are overweight and force drivers to "bend the rules" to stay employed. One driver stated that "in order to compete with fly by night drivers, sometimes you have to just do what you are told and deliver a load, even though you are not sure of what you are carrying." When researchers probed the driver further about this, the driver responded by informing researchers that many port operators and companies will not properly identify hazardous materials and drivers are forced to transport loads that they feel are unsafe. Both drivers report knowing several owner-operated trucking companies, with one driver driving his own truck, that have received numerous violations and have simply shut down and reopened under a new name.

In addition to these problems, the expert also identified California's strict emissions restrictions as a major burden on his company and the drivers his company works with. According to the expert, companies with commercial vehicles registered in the state of California have to buy California Air Resources Board (CARB) diesel fuel. According to the expert, this fuel is expensive and as a result many owner-operated commercial vehicle companies are now registering their vehicles in Nevada and buying their fuel out of state. This enables the truckers to avoid California's emissions standards and the costs associated with purchasing CARB diesel.

The expert suggested several possible solutions to address the problems outlined above. First, the expert would like to see the CHP redeploy their resources by inspecting smaller owner-operated trucking companies and stop focusing on the larger trucking companies. The expert would like to see a CHP crackdown on truckers using non-truck routes, on companies that do not keep accurate logbooks, on companies that do not carry insurance, and would like to see more responsibility assigned to the ports.

The expert identified the junction of the 405 and 710 freeways as a problem location. This area is near the Port of Long Beach and leads into downtown Los Angeles. The expert believes that over 50,000 trucks travel through and around this junction each day. He believes that thousands of these trucks are overweight and would like to see the ports certify truck loads before the trucks ever leave the port.

The expert and his company support the use of mobile VWS technologies to identify overweight vehicles, improve roadway safety, electronically check truck credentials and for homeland security purposes. The expert believes that fixed sites are easy for truckers to avoid and that mobile units would allow the CHP to "crackdown" on violators. The expert stated that although he is the vice president of a trucking company, he supports the use of these technologies because it will streamline his business and expose truckers who violate the law. The expert supports the use of these technologies in all locations but would prefer to see them deployed at or near the ports.

The drivers also support the use of VWS technologies and believe that this technology can save them money by reducing time spent at weigh stations. The drivers would both prefer to have more liability and responsibility placed on the ports and would like weights to be certified prior to leaving the port.

The expert believes that VWS technologies are beneficial but that cargo should be screened more rigorously before it ever enters U.S. ports. The expert fears that if a weapon of mass destruction was deployed at a U.S. port the entire global economy would be impacted.

The expert and the drivers do not have much knowledge of or experience with the PrePass program because the company deals with short hall or short distance trucking.

The expert and his company support the use of VWS technologies if an officer is present but do not support the use of a fully automated system. The expert feels that VWS technologies should be used to identify possible violators and then an officer should be dispatched to intercept the truck and use a handheld scale to weigh the truck. The expert feels that the technology may be faulty and an officer should always be involved.

The drivers agree and would like to see VWS technology used only if an officer actually stops the truck and then conducts a roadside inspection or escorts the truck to a static scale.

The expert would like to see national standardization for both commercial vehicle license plates and DOT numbers. He supports this standardization because he belives it will enable trucks and goods movements to be tracked more efficiently.

The expert believes that good trucking companies that follow the law will support the use of VWS technologies and small "fly by night" companies that try to evade weigh stations will oppose it. The expert also questions how law enforcement will view the use of VWS technologies. He feels that they might oppose it because it would streamline the truck inspection process and require fewer officers to staff the weigh stations.

2.5 Interview 5

The fifth stakeholder/expert interview was conducted with the President of Transportation Data Systems. This company designs, installs and maintains vehicle classification systems, electronic tolling systems, license plate reader technology and weigh in motion technology. The expert has worked for the company since it was founded 11 years ago.

The expert was able to provide researchers with his company's organizational perspective on the problems/weaknesses associated with current commercial vehicle enforcement/inspection processes. The expert feels that there are too many trucks traveling on roadways throughout the United States and that it is impossible to inspect and track them all with traditional enforcement techniques.

The expert informed researchers of a project in Southern Florida involving the placement of sensors on freeways located on ramps and off ramps, near the Punta Gorda Weigh Station, where trucks are bypassing the scales by exiting and reentering the freeway. The expert provided researchers with the project manager's contact information from the Florida Department of Transportation.

The expert and his company advocate for the use of fixed sensors and imaging technology to identify overweight vehicles; imaging technology to identify license plates and DOT numbers; digital short-range communication (DSRC) devices to improve roadway safety by ensuring that trucks maintain good safety records and proper credentials (also known as electronic credentialing), screening for bad brakes and sensing expired inspection tags; cameras and license plate readers to improve homeland security by monitoring stolen vehicles that have the potential to be used as weapons and monitoring border crossings; and gamma ray detectors to screen for illicit cargo, human trafficking and potential weapons in goods movement. The expert and his company support the use of these technologies in all locations and on all types of roadways (e.g., truck-only routes, alternative routes used to avoid inspection stations, rural roads, urban high-volume roads, ports, bridges and at border crossings).

According to the expert, his company's fixed weight sensors are similar to mobile or portable weight sensors and are very different from other fixed weight sensor technology. According to the expert, his WIM system can be placed over a roadway, unlike traditional fixed sites where the weight sensors are placed in the concrete. According to the expert, placing weight sensors in concrete creates serious problems. If the sensor malfunctions it can force the closure of roadways while the concrete is removed, equipment is replaced and roadways are repaved. Transportation Data System's weight sensors are placed in a container, which goes into the concrete approximately two to three inches. If a sensor malfunctions the container can be opened and the sensor can be easily repaired or replaced without any disruption to the concrete roadway. According to the expert, this technology can even be used on bridges.

The expert also believes that VWS technologies should be used to identify emissions violations by using emissions sensors to identify gross polluters and imaging technologies to improve enforcement in residential areas where trucks are prohibited. However, according to the expert, this technology is not reliable or accurate and is difficult to implement. The expert would like to be involved with more research in this area.

The expert believes that the solution for the overwhelming number of trucks traveling on roadways in the U.S. is to deploy fully automated virtual weigh stations. The expert and his company also wants to see a national standard for license plate placement, color, font size and DOT numbers as well. According to the expert, this standardization is the first step in truly tracking and monitoring truck travel and goods movements.

The expert believes that the CHP and other law enforcement agencies would support the deployment of VWS technologies because the use of these technologies would make the roadways safer and relieve some of the burden that commercial vehicle inspections place on law enforcement. According to the expert, insurance companies would also support the use of this technology because tracking and reducing overweight trucks would decrease the number of trucks involved in crashes, thus saving insurance companies money.

The expert believes that "privacy people" will oppose the use of these technologies. He also believes that many trucking companies will oppose the use of these technologies because many of them currently avoid weigh stations and do not "practice good trucking" or "operate by the letter of the law."

The expert is eager to be involved with the advisory board. The expert would like to work in conjunction with Caltrans to deploy weight sensors around the Ports of Long Beach and Oakland. The expert stated that his company is willing to provide the equipment for a data collection project and he is eager to discuss this with Caltrans.

2.6 Interview 6

The sixth expert/stakeholder interview was conducted with the Transportations Manager for the Port of Long Beach. The expert was able to speak to researchers from his organization's perspective and identified several problems associated with the current commercial vehicle inspection/enforcement process in California.

According to the expert, there is currently a misconception among researchers and law enforcement about the number of overweight vehicles traveling on California's roadways. The expert believes that there are fewer overweight trucks than law enforcement estimates. The expert could not provide any data to support this claim. According to the expert, trucks produce excessive emissions when idling at weigh stations, thus creating poor air quality. The expert feels that problems associated with trucks idling at weigh stations and owner-operated trucks are the biggest problems/weaknesses associated with the current inspection process.

The expert believes that many owner-operated trucks do not carry proper insurance or licenses and avoid inspection stations. The expert identified the 710 Freeway as a problem location. According to the expert, this freeway does not have an inspection station. The expert informed researchers that the CHP often sets up "sting operations" to track and catch overweight or noncompliant trucks. The expert believes that many trucks avoid the 710 Freeway and use an access road next to the freeway, or neighborhoods surrounding the freeway, to avoid being stopped and inspected by the CHP.

The expert also identified the 405 and the 110 freeways as problem locations where trucks use non-truck routes to avoid the CHP. According to the expert, the 110 Freeway once had an inspection station that is no longer in use, and trucks often use non-truck routes and neighborhoods to avoid the 405 inspection station.

The expert believes that many owner-operated trucks close down and reopen under a new name if they are stopped and cited by the CHP. According to the expert, there is high turnover among owner-operated truckers and it is difficult to track credentials and safety information. The expert also believes that many truckers come from Nevada and operate in California to avoid the emissions standards in California. The expert is going to provide researchers with data on California registered trucks verses out of state registered trucks currently operating out of the Long Beach Port.

The expert and his organization believe that new VWS technologies would help reduce the problems outlined above. The expert and his organization support the use of portable sensors placed on roadways that can be used to identify overweight trucks.

The expert is hesitant to support traditional CVEF because of the delays associated with trucks idling while waiting for inspections and would prefer the deployment of VWS systems. The expert and the Port support the use of both mobile and fixed VWS sites but prefer mobile sites. The preference for mobile sites stems from the expert's desire for the CHP to catch noncompliant trucks in varying locations surrounding the ports.

The expert also prefers the use of DSRC and RFID devices to track trucks and goods and would like to see PrePass and electronic credentialing become mandatory. The expert also supports the use of technologies that are capable of identifying gross polluters but believes that this technology is not yet ready to be deployed in the field due to inaccuracies.

The expert and his organization also support the use of VWS technologies to improve homeland security. The Port is currently using technology with license plate reading, optical characteristics and traffic monitoring to monitor and track trucks entering and exiting the Port.

The expert would like to see the technologies discussed above used in and around the ports. He would also support the use of these technologies in all other locations, as long as traffic disruptions were not caused by their use.

The expert and his organization also support the use of both manned and unmanned units but prefer a combination of both. The expert believes that due to the number of trucks currently on the roadways, unmanned units may be deployed sometime in the future but having an officer dispatched to intercept a suspected violator would be easier to implement.

The expert also believes that creating national standards for the placement, color and font of commercial vehicle license plates and DOT numbers is good and uniformity will allow for better tracking and enforcement.

The expert could not comment on where the major support and opposition to VWS lies.

The expert is interested in participating in an advisory capacity.

2.7 Interview 7

The seventh stakeholder/expert interview was conducted with an expert who has worked as a consultant with the PrePass program for four years and oversees maintenance of all PrePass sites in California and nationwide. Before working with PrePass the expert worked for the California Trucking Association (CTA) and prior to his work with the CTA, the expert was a CHP officer in the commercial vehicle enforcement unit. The expert was able to provide researchers with the PrePass program's perspective during the interview.

When the expert was asked about weaknesses/problems with the current commercial vehicle inspection process, the expert informed researchers that the current system in California works better and is more efficient than any other program in the nation. The expert believes that the major problems associated with commercial vehicle inspections and enforcement have to do with a lack of maintenance of current weigh scales and weigh in motion sites (WIM). The expert informed researchers that the CHP is currently upset with Caltrans over maintenance of weigh scales. The expert believes that the CHP's commercial vehicle enforcement unit is doing an excellent job by conducting bi-annual inspections, which involve the CHP entering trucking companies and examining records and logbooks.

When the expert was asked about different types of VWS technologies and applications of these technologies, the expert expressed concern over the accuracy of WIM sites. The expert believes that WIM technologies should not be used for enforcement purposes due to the inaccuracies associated with the technology. He also believes that only an officer can determine if a vehicle is non-compliant or overweight because the WIM technology is unreliable. The expert cited the Cordelia WIM site as an example of a system with high maintenance costs and low reliability.

The expert continued by stating that the PrePass program currently serves over 65,000 motor carriers and approximately 376,000 trucks are enrolled nationwide, with 316,000 in California. In addition, the expert believes that the PrePass program already does what WIM sites do and are more reliable than WIM sites.

The expert believes that the PrePass program should be mandatory for all trucking companies, including small owner-operated companies. He feels that his program helps alleviate congestion at weigh scales, eases CHP's burden by streamlining commercial vehicle inspections and is more cost-effective when compared to the maintenance associated with building CVEF.

2.8 Interview 8

The eighth expert/stakeholder interview was conducted with an expert who has over 23 years of experience working with Caltrans and is a senior engineer and program director responsible for overseeing all of the weigh in motion (WIM) sites for the state of California. Due to the expert's extensive knowledge regarding WIM technology, the expert was able to provide researchers with several problem locations where he believes WIM or VWS technologies should be deployed. The expert outlined the current commercial vehicle inspection process in California and stated that the CHP cannot inspect and track the massive volume of commercial trucks currently operating on California's highways. For example, the expert identified locations on the 405, 110 and 710 freeways that he estimates carry over 50,000 trucks per day. According to the expert, the CHP deploys inspection officers on these freeways to identify and catch violators, including overweight and gross polluters. According to the expert, the sheer number of trucks using these freeways overwhelms the limited resources and manpower available to the CHP and the CHP can only inspect a small number of these trucks each day.

According to the expert, the 710 Freeway is a particularly difficult area for commercial vehicle enforcement due to limited land availability. The 710 is a two-lane highway with the Los Angeles River on one side; subsequently, there is not enough land available to pull trucks over. According to the expert, when the CHP finds a violation they have to put the truck out of service; when land and space is limited this poses several challenges; including traffic congestion, air pollution and roadway safety hazards. According to the expert, a traditional inspection station on the 710 is estimated to cost between 30 million and 1 billion dollars. The expert informed researchers that this is not feasible and that the only possible solution is to deploy a fully automated VWS system.

In addition, the expert identified several locations in the state where trucks bypass inspection stations by using alternative or non-truck routes. The expert identified a problem location outside of Los Angeles where trucks traveling down Interstate 5 bypass the 101 inspection station by taking the 126. Trucks traveling on the 126 drive directly through the city of Moore Park thus causing concern among residents of the city.

To address these problems the expert believes that portable WIM scales should be deployed at locations throughout the state, including locations on highways 37, 40 and 118 freeways, which are located in San Bernadeno County. The expert informed researchers that trucks traveling on these routes are usually coming from rock queries and are often overweight. According to the expert, these trucks damage the roadways, pose a danger to other drivers sharing the roadways with them and are difficult to track because of the sheer volume of trucks traveling on these roadways.

The expert believes that creating a national standard for the size, placement and color of license plates and DOT numbers would allow for easier tracking of commercial trucks.

The expert has had many years of experience working with WIM technologies and believes the technology is accurate, and deploying portable weigh scales would be the most cost-effective way to reduce the number of overweight or non-compliant trucks operating on California's roadways. Furthermore, the expert suggests that the state deploy portable scales at rest stops frequented by truckers. The expert would like to place weight sensors in the roadways or use portable scales and lights (such as those used for PrePass) on roadways before rest stops. A possible scenario is as follows: as a truck approaches the rest stop, a light shines green to indicate that it is weight-compliant or red, indicating that the truck is overweight and needs to pull into the rest stop where CHP officers can inspect the vehicle. The expert believes this idea would cut down on construction costs associated with building inspection stations and also address the issue of limited land availability.

The expert supports the use of VWS technologies on all types of roadways and in all locations (i.e., truck-only routes, alternative routes used to avoid inspection stations, rural roads, urban high-volume roads, ports and bridges). The expert believes that these technologies can be used to track overweight vehicles, improve homeland security and increase roadway safety.

The expert believes that CHP is somewhat resistant to the use of VWS technologies because current CVEFs are poorly maintained and often out of service.

2.9 Interview 9

The ninth stakeholder/expert interview was conducted with an expert from the Federal Motor Carriers Safety Administration (FMCSA). The expert was able to provide researchers with information about current commercial vehicle inspection processes, the capacity of the current system and problems associated with it.

The expert informed researchers that the FMCSA obtains commercial vehicle inspection data from state agencies such as the CHP. According to the FMCSA, approximately 3,000,000 commercial trucks are inspected in the U.S. each year. The FMCSA would ideally like detailed truck inspections (i.e., weight, brakes, frame and emissions) about every 13 months. However, the expert believes that some trucks are inspected all the time and some trucks (due to their routes) are never inspected. The expert outlined what he believes are the greatest weaknesses and problems associated with the current inspection/enforcement system, including a lack of resources at the state level.

The expert estimates that the number of commercial trucks increases approximately three to five percent each year. However, the number of enforcement facilities and inspection officers are not increased to match this increase in trucks. The expert believes that the commercial vehicle inspection/enforcement system in California is one of the best in the nation; however, there are simply not enough inspection officers to thoroughly inspect all of the trucks on the roadways.

When asked about the use of VWS technologies, the expert stated that the FMCSA supports the use of these technologies on all types of roadways (i.e., truck-only routes, alternative routes used to avoid inspection stations, rural roads, urban high-volume roads, ports and bridges). The expert believes that the use of wireless technologies to check truck credentials will reduce congestion at weigh stations and will cut fuel costs for commercial vehicle operators.

The FMCSA supports the use of both mobile and fixed weigh scales and believes that a combination of these technologies can be used to track, inspect and regulate more trucks. The expert recognizes the costs associated with building CVEFs and believes that states are not willing to pay for these sites. He feels that mobile VWS units (which do not cost as much as fixed sites) are great alternatives.

The expert provided researchers with an example of a project in Florida that has 30 WIM sites. According to the expert, Florida had a problem with trucks bypassing inspection stations. In order to address this problem, the Florida Department of Transportation deployed mobile weigh scales and video data processing technologies on off ramps and roadways used by truckers to avoid inspection stations. The expert believes that an important lesson learned from this project is to manage the data and find a way to use the data for enforcement purposes.

The expert believes that national legislation should be passed to regulate DOT numbers (i.e., color, size, font and placement) and link DOT numbers to Vehicle Identification Numbers (VIN). This would allow inspection/enforcement agencies to track trucks and regulate violators more effectively. According to the expert, the current system can be abused by commercial vehicle operators that close down their trucking business once they have been cited for weight or safety violations and reopen under a new name. The expert believes that tying the VIN and DOT numbers together would greatly reduce this abuse of the system.

The expert informed researchers that it would be virtually impossible to create any type of national standard for commercial vehicle license plates due to state laws.

The expert could not comment on where the major support or opposition to VWS may lie.

2.10 Interview 10

The tenth stakeholder/expert interview was conducted with a WIM engineer working with Caltrans Traffic Operations. The expert oversees all WIM sites throughout the state of California including the WIM design phase, contract negotiation, WIM construction, calibration and data collection and processing.

When asked about current problems and weaknesses associated with the current commercial vehicle screening/enforcement process in California, the expert provided researchers with an overview of both traditional CVEF and WIM sites.

According to the expert, traditional weigh scale sites often become overcrowded and trucks frequently back up onto freeways. This poses several problems, including roadway hazards caused by trucks waiting to be screened; emissions concerns caused by idling trucks; and truckers driving overweight vehicles who wait and count the number of trucks forming lines at weigh stations, and once the CVEF is shut down because of overcrowding, know that it is safe to bypass the CVEF.

The expert believes that WIM sites try to alleviate some of the problems associated with traditional commercial vehicle enforcement. However, the expert pointed out several problems associated with the maintenance of WIM sites, including harsh weather conditions damaging equipment and high traffic volume wearing down sensors. The expert stated that WIM sites are often shut down when the weather is either too hot or too cold because the bending plates become loose. Other problems outlined by the expert include rodents eating the wiring connected to the pole boxes and the phone lines owned by SBC and AT&T going out, which means the site loses its wireless connection and cannot operate.

Furthermore, the expert believes that the maintenance costs associated with WIM sites are much higher than that of traditional CVEF. However, the expert was unable to provide researchers with any data on maintenance costs. According to the expert, in the last 6 months seven to eight bending plate frames had to be replaced. This means that a stretch of roadway had to be closed for approximately six to eight hours while the concrete was jack hammered out in order to get to the frame, which is under the roadway. In addition, the expert stated that problems with sensors often occur, which require roadway closures for two to three hours at a time; and motherboards and software often go out.

When asked about mobile VWS systems verses fixed systems, the expert stated that portable or mobile scales are less expensive when compared to building a fixed site. However, the expert feels that mobile scales are less reliable and they are not durable.

When asked about problem locations, the expert identified Interstates 10 and 15. These freeways stretch from Las Vegas to Southern California. According to the expert, there are no scales on the Mountain Pass. Researchers also questioned the expert about other problem locations in Southern California, including the 710 Freeway. The expert responded by saying, "Stay out of Caltrans District 7- they do not allow road closures for roadway maintenance because of the high traffic volume."

Furthermore, the expert believes that VWS technologies are limited in their ability to accurately check some safety-related issues including tire pressure and brakes. On the other hand, the expert believes that trained CHP officers can visually examine a passing truck and identify safety-related problems.

In addition, the expert feels that emissions sensing technologies are still in a research phase, and CHP officers and field technicians from the Air Resources Board (ARB) can quickly and effectively identify gross polluters and selectively screen trucks based on what they see verses using emissions sensing technology.

However, the expert believes that because the number of trucks operating in California continues to increase each year, more WIM sites, and possibly VWS, will be deployed to try and meet the need for increased inspections. In regard to Virtual Weigh Stations, the expert feels that the CHP will oppose these sites because the number of inspections officers would be reduced.

When questioned about the PrePass program, the expert stated that he felt the technology works well but is often abused by devious truckers that switch and share transponders.

On August 17, researchers had the opportunity to visit the Alverda WIM site, located on Interstate 80 East of Sacramento, with the expert. The expert explained to researchers that the WIM site was not functioning properly. The expert informed researchers that Caltrans uses IRD technology and software for 115 out of 116 WIM sites. The information collected at these sites is used to develop truck counts and traffic volume and flow information but is not used for enforcement purposes. The data collected at these sites is automatically downloaded onto a computer at Caltrans WIM Division. If the data has inconsistencies or inaccuracies, the validation system alerts engineers to the potential problem. On this particular day, the WIM system was experiencing problems associated with axle counts and weights. Researchers observed the system report a truck with seven axles and a weight of over 700,000lbs. The expert informed researchers that Caltrans has a contract with IRD to calibrate the WIM systems about every eight to thirteen months. The expert identified infrequency of calibration as a major limitation of the current WIM systems used in California. The expert stated that due to a lack of calibration, current WIM sites could never be used for enforcement purposes and Caltrans does not have the money to pay for more frequent calibrations.

2.11 Interview 11

The eleventh stakeholder/expert interview was conducted with an expert who works with Caltrans in the research division. The expert provided researchers with an overview of problems associated with the current commercial vehicle enforcement/screening process in California. The expert identified short hall trucking as a major problem in California because ofdue to the difficulties associated with tracking these vehicles, the routes they use and the loads they carry. The expert believes that the short hall trucking industry operates with almost no regulations. For example, the expert stated that short hall truckers often travel on city streets sometimes because traveling through a city is the shortest distance to where the load must be delivered, and sometimes driving through a city or on a non-truck route is done to avoid inspection facilities.

Furthermore, the expert informed researchers that short hall truckers are often paid cash to carry loads and are paid for each run or load they deliver. This means that the more loads a trucker delivers, the more money he can make. Being paid in cash makes it difficult to track the load. The expert suggested that researchers ask the CHP about the types of trucks that are frequent violators. The expert believes that short hall trucks are usually owner-operated trucks, do not belong to a large company, are poorly maintained, are often gross polluters and pose a safety hazard due to a lack of brake inspections and other safety inspections.

The expert identified several problem locations throughout California including the ports. The expert described the ports as “the worst offenders.” The expert elaborated by stating that the Port of Oakland does not have a CVEF or WIM nearby and trucks leaving the Port often cut through the city of Oakland, creating emissions and air quality concerns. The expert also outlined several concerns related to the Ports of Los Angeles and Long Beach, including the sheer volume of trucks entering and exiting the ports, which creates a traffic nightmare on the surrounding roadways and freeways. The expert stated there are at least seven routes leaving the ports and the 710 Freeway is often overcrowded with trucks in every lane. The expert informed researchers that the 710 has five lanes heading north and four lanes heading south. According to the expert, trucks drive in every lane instead of the two right lanes.

In addition, the expert stated that there is no place to weigh trucks on the 710 and that CHP deploys mobile enforcement units, but they simply cannot handle the volume of trucks in this area. The expert estimates that over 50,000 trucks use this freeway everyday.

The expert also suggested that researchers examine the Ports of Sacramento and Stockton and determine the number of trucks operating in and around these locations. The expert speculated that these ports may have seasonal problems associated with the agricultural industry of the Central Valley.

Another problem location identified by the expert is the 405 Freeway. According to the expert, a truck hit the scale house and destroyed the weigh station. Due to a lack of funding this site has not been rebuilt.

The expert outlined several ways in which truckers can make it difficult to track their weight at weight scales, including truckers carrying liquid loads speeding up rapidly as they go over the weight scale, causing the weight of the load to shift off of the front axles, and then braking quickly to cause the weight of the load to shift from the rear of the truck to the front axles as the truck passes over the weight scale.

The expert supports the use of VWS technologies but emphasizes that these technologies will not work in all locations. According to the expert, it is crucial to place weight sensors on smooth roadways in order to ensure the accuracy of the weight readings.

2.12 Interview 12

The twelfth expert/stakeholder interview was conducted with the Chief of Mobile Sources Enforcement from the California Air Resources Board (CARB). The expert oversees enforcement for all on-road vehicles including heavy duty or commercial vehicle emissions enforcement for the state of California.

According to the expert, the goal of the CARB is to reduce emissions output produced by heavy duty diesel trucks by ensuring that there are fewer hydrocarbons and smog-causing particulates in the air including carbon monoxide..

The expert outlined the Clean Air Act of 2005, which changed the CARB specifications from 500 parts per million to 15 parts per million, making California's emissions standards the strictest in the nation. The expert informed researchers that emissions enforcement starts with diesel engine manufacturers. For example, the expert outlined a 1998 CARB lawsuit against diesel engine manufacturers (including Dodge) that were building engines that reduced the amount of fuel going into the engine, which caused the truck to release more nitrogen, called "cycle beating" or "reflashing." According to the expert, CARB won this lawsuit and diesel engine manufacturers have to fix the problem engines by reprogramming the computers. It is the responsibility of CARB to test sample engines to ensure that the appropriate changes have been made.

The expert outlined several ways in which the CARB tries to enforce emissions regulations by regulating the types of fuel used by commercial trucks. According to the expert, commercial vehicles registered in the state of California must buy and use CARB diesel, which is supposed to burn cleaner and reduce emissions. The CARB samples fuel at both mobile fuel labs, which use gas promatogaphs; and fixed labs, such as the one in Pasadena, which examines emissions output by examining a 30 second sample of exhaust. According to the expert, the CARB sampled over 118,000 gallons of diesel fuel in 2005, found 20 violations and issued $75,000 in fines.

The CARB also inspects diesel fuel at refueling stations (truck stops) to ensure that the fuel being sold in California meets the CARB specifications. The expert informed researchers that there are very few violations at these locations.

In addition, the CARB inspects commercial trucks at ports of entry including border crossings. The expert stated that there is a problem with vehicles registered outside of the state operating within California but not complying with California's emissions regulations. According to the expert, in 2005, 17,243 commercial trucks were inspected by CARB at ports of entry and border crossings and eight percent failed to meet California's emissions specifications. The expert stated that NAFTA has created a problem with gross polluters crossing from Mexico into California and 14% of the trucks inspected at the border crossings in 2005 failed to meet California's emissions standards. The CARB issued $420,000 in fines for emissions violations in 2005 and were successful in collecting $417,000 in fines. The expert informed researchers that the CARB tracks vehicles by VIN to avoid owner-operated truckers who receive tickets from closing down their business and reopening under a new name.

When asked about the performance and capacity of the current commercial vehicle emissions enforcement process, the expert informed researchers that the workload is extremely high. The expert stated that his budget allows for 13 positions for vehicle emissions enforcement, including commercial vehicle enforcement, for the entire state of California and 20 positions for fuel enforcement.

When questioned about the use of VWS technologies to identify gross polluters, the expert stated that he felt the technology still needed more research and he did not feel it was very reliable. The expert believes that although resources are limited, trained CHP officers and CARB technicians can visually identify gross polluters and then bring the trucks in for a smoke opacity test. The expert believes that technology will someday allow for more accurate testing of emissions output while trucks are in motion but the technology is currently still in a research phase.

2.13 Interview 13

The thirteenth stakeholder/expert interview was conducted with an expert from International Road Dynamics (IRD). The expert provided researchers with some background information on his company and the different types of technologies offered to customers. The expert informed researchers that IRD is a Canadian company that "supports projects with preventative, scheduled and emergency maintenance through a network of service offices." IRD contracts with many companies and state departments of transportation, including Caltrans. Some of IRD's technologies include traffic sorting systems, providing safety messages to vehicles, calculating tolls and collecting important data, such as the weight of commercial vehicles. In addition to traditional maintenance contracts, IRD also maintains third party equipment. The expert also provided researchers with an overview of IRD's fleet management systems, which are vehicle information systems that are built to meet the client's specific needs and allows clients access to fleet vehicle information such as speed, cornering, vehicle acceleration and braking. Some systems use audio feedback to help drivers drive safer.

When asked about VWS technologies, the expert informed researchers that IRD designed its WIM systems to provide remote enforcement to law enforcement agencies including the CHP, to allow for commercial vehicle enforcement in areas where it would be difficult to pull over a truck, and also to provide enforcement in rural areas where there are few inspection sites or law enforcement officers.

When asked about fixed verses portable VWS technologies, the expert informed researchers that static weight scales are the most accurate with an error of +- 10 percent. However, both fixed and portable sites can be designed to be accurate and reliable. The expert emphasized the importance of placing portable weight sensors (PAT electronic bending plates) on level stretches of roadways. According to the expert, sloped or uneven roadways can cause inaccurate weight readings. In addition, the expert believes that portable scales are a beneficial enforcement tools because they provide mobility and allow for enforcement in multiple locations, and are less expensive when compared to static or fixed weight sites.

When asked how IRD's technology can be used to improve commercial vehicle safety, the expert outlined the tire pressure system, which uses infrared technology to determine how hot or cold brakes are. IRD also has a vehicle alert system which notifies the driver if an animal or a piece of debris is in the roadway.

When asked about homeland security applications, the expert outlined Arizona's EPIC program, which tracks commercial vehicles at border crossings and allows for electronic credentialing at border crossings. The expert believes that this technology can be used to track goods movements and hazardous materials.

When asked about emissions sensing technology, the expert informed researchers that the technology thus far is not reliable and IRD is not conducting research in this area.

2.14 Interview 14

The fourteenth expert/stakeholder interview was conducted with the Administrative Manager of the Port of Sacramento. Researchers were invited to meet with the expert and take a tour of the port. The expert informed researchers that port management had recently changed. According to the expert, port administrative staff and management are currently developing a strategy to diversify the types of freight shipments coming in and out of the port. The expert described this time period as "a period of transition and revitalization for the Port of Sacramento."

Researchers were able to tour the terminals where freight is offloaded from ships and loaded onto commercial trucks. When asked about the types of freight entering and exiting the port, the expert informed researchers that fertilizer, pesticides and agricultural goods are the primary goods transported out of the port to the Central Valley. Fruits and vegetables are the major goods exported from the port. The expert informed researchers that the Port of Sacramento is in competition with the Port of Stockton; both ports import and export similar goods to the Central Valley.

When questioned about VWS technologies, the expert stated that the port only has a few hundred trucks operating out of the port each month. Each truck is weighed on arrival to the port and then again prior to exiting the port. The expert stated that most trucks arrive to the port empty and a baseline weight is established, and once the truck has its cargo port operators weigh the truck and the weight is noted in the driver logbook. The trucks are weighed using a traditional weigh scale. Researchers observed trucks pulling up to the scale, stopping and then driving onto the scale and stopping again while waiting for a weight reading. Once the weight was established the trucks drove off of the scale.

The expert was familiar with VWS technologies but stated that the Port of Sacramento does not have the high volume of truck traffic associated with large ports such as LA/Long Beach or even the Port of Oakland. According to the expert, approximately 250 to 500 trucks operate out of the port in a typical month. For example, the expert informed researchers that for the month of July only 300 trucks entered the port. The expert stated that a majority of the trucks operating out of the port are owner-operated tucks and very few trucks belong to companies or fleets. Researchers asked the expert if truckers were paid by load or in cash for their deliveries. The expert responded by stating, "Maybe, I don't know."

The expert mentioned that the CHP often sets up commercial vehicle stings on Interstate 5 and Highway 99 because many trucks only travel from the Port of Sacramento to the Central VVWS meeting on Oct 5thalley (approximately 75 – 100 miles) and never pass inspection stations.

When asked about VWS technologies that can potentially be used for security purposes, the expert informed researchers that the Port of Sacramento has private security. According to the expert, security monitors who enters and exits the port. When asked if photos of vehicle license plates were taken for vehicle identification purposes or tracking of goods movements, the expert responded by stating, "The port does not use anything like that." The expert informed researchers that some companies that ship products (fertilizer) into the port use RFID tags to track their goods but not the trucks.

While at the port, researchers observed a total of five trucks in the terminals being loaded with goods. Another three trucks were idling without drivers and two were weighed prior to exiting the port. The expert stated that the port is generally not too busy and it is very easy for port operators to ensure that each truck is weighed.

2.15 Interview 15

The fifteenth stakeholder/expert interview was conducted with an expert from the California Air Resources Board (CARB) who is responsible for creating emissions standards and guidelines for heavy duty diesel engines (commercial trucks) for the state of California.

When questioned about how CARB creates standards and guidelines for diesel engine emissions, the expert provided researchers with an overview of how these standards are determined. According to the expert, an inventory work model has been created that produces a cost benefit analysis of the cost of implementing a new standard compared with its ability to reduce emissions produced by diesel engines (commercial trucks). According to the expert, factors such as estimated benefits, estimated emissions reductions, emissions factors, and cost-effective measures for addressing emissions related problems are used to determine an emissions standard or guideline called an "In-Use Compliance Standard."

The expert outlined how these compliance standards are written and some problems associated with enforcement of these standards. For example, emissions standards are written to allow for a certain amount of emissions but set a "not to exceed" standard which determines the level of emissions that trucks must stay under. When asked about how these standards are enforced, the expert stated, "That is the problem." The expert informed researchers that limited resources and the costs associated with testing diesel engine emissions prohibit the guidelines and standards set forth by the CARB and the Environmental Protection Agency (EPA) from being adequately enforced. The expert informed researchers that in order to adequately test a diesel engine the engine must be placed on a machine called a dynometer. The expert estimates that each dynometer test costs approximately $25,000 per engine.

As a result, many engine manufacturers and trucking companies are responsible for self policing. According to the expert, over 25 different diesel engine families exist and the CARB simply does not have the resources available to conduct inspections of each truck to ensure they meet emissions standards. The expert believes that although California may have the most strict emissions standards in the nation, many trucks operating within the state fall short of these standards.

In addition, the expert informed researchers that during a typical commercial vehicle inspection, most trucks are not tested to ensure they are in compliance with emissions standards.

Researchers questioned the expert about VWS technologies that can be used to help with emissions enforcement, including remote emissions sensing technologies. The expert believes that such technologies could be a beneficial tool that can potentially be used to streamline the inspections process and ensure that more heavy duty diesel engines are operating within California's emissions guidelines. The expert feels that the technology needs to be researched further because it is not yet reliable and it is difficult to get an accurate emissions reading from a truck in motion.

2.16 Interview 16

The sixteenth stakeholder/expert interview with a representative from the Port of Oakland. The expert is the Manager of Rail and Maritime Development. This includes updating and rebuilding railways to increase railway fluidity and working with the city of Oakland and Caltrans to improve the roadways surrounding the port.

When asked about the Port of Oakland's interests in VWS technologies, the expert provided researchers with an overview of how trucks are currently used to move freight in and out of the port and how the use of VWS technologies could possibly be used to streamline this process. The expert stated that efficiency is the most important factor the port considers when implementing any new policy or technology. According to the expert, the port and terminal operators make money based on the number of containers they are able to ship in and out of the port. According to the expert, it is in the port's interest to make this process go as fast as possible.

According to the expert, the port is interested in VWS technology that could potentially be used to enhance the port's gate system. According to the expert, gate congestion and the lack of a centralized gate forces the Port of Oakland to operate at about 60 percent of its capacity. Currently, the port has several gates or ways to enter and exit. The expert informed researchers that port managers are interested in a virtual or automated gate system, capable of identifying both the truck, the driver and the container, using optical characteristics technology and RFID tags. The gate would automatically notify the appropriate terminal that the truck would be arriving at the terminal. The expert believes that this system would allow terminal operators to be prepared to receive, assign a location and unload the truck. The expert also believes that having a centralized automated gate will improve port security because the system would allow U.S. Customs and the Coast Guard to know which terminal each truck has been assigned and in turn increase the number of inspections. Currently, trucks arrive at the port, drive to the terminal and wait at the terminal until terminal operators have time to process the trucks' paperwork. According to the expert, this wastes both the truck drivers' and the terminal operators' time.

At this time, the expert was unable to provide researchers with feedback on mobile verses fixed, and semi0atuamted verses fully automated systems.

When asked about problems/weaknesses with the current import/export system at the port, the expert outlined several problems the port would like to address. First, port operators and managers are concerned over the amount of cargo currently being screened. According to the expert, U.S. Customs and Coast Guard are responsible for screening cargo. The expert estimates that less than five percent of cargo is X-rayed with a mobile machine. Every piece of cargo goes through a gamma ray detector; however, the expert feels that the lack of a streamlined system allows for mistakes.

Furthermore, the expert informed researchers that each terminal has its own system of receiving trucks and security plans in place. The expert believes that the port should have some type of uniform security plan in case of an emergency.

Interestingly, cargo brought into the port by truck are weighed prior to being loaded onto a ship and exported. According to the expert, shipping companies insist on having a certified weight for each cargo container. This allows for containers to be properly placed on ships. However, trucks leaving the port are not weighed. The expert stated that many trucks are weighed when they reach weigh stations on Interstates 5 and 80.

The expert was asked about short hall trucks that do not operate on freeways but instead use local roadways to deliver their goods. Researchers asked the expert when he thought these trucks were weighed or inspected. The expert informed researchers that these trucks are weighed only when bringing cargo into the port for export. The truck frame may be inspected by the Coast Guard during a cargo inspection but many short hall and medium hall trucks are never inspected.

The expert informed researchers that the port has a broader concern over roadway congestion and supports the use of any VWS technologies that can keep trucks moving once the trucks are operating on roadways outside of the port. The expert identified Interstate 5 and 80 and Highways 580, 880 and 99 as areas with heavy truck congestion. According to the expert, when trucks have to stop to be weighed at a static scale both time and money are lost. The expert believes that if VWS sites can be deployed to keep trucks moving the port would support it.

When asked about the number of trucks operating out of the port each day, the expert informed researchers that he would have to provide that information at a later date. However, the expert did tell researchers that 30 percent of cargo is shipped out of the port via rail and 70 percent by truck. Goods such as car parts (going to the Hyundi plant) and electronics are imported into the port and then carried by truck to Sacramento, San Jose and the Tri-valley areas. Goods such as wine, beer, and agricultural products are brought into the port via truck and exported overseas.

The expert also identified problems associated with air quality as a major area of concern for port operators and management. According to the expert, trucks often park in the areas surrounding 7th Street and Maritime while waiting for the port gates to open early in the morning. According to the expert, truck traffic is usually the only traffic in this area. However, the city of Oakland is concerned about trucks idling around the port and the air quality concerns associated with this. According to the expert, this is an area where the port feels vulnerable because they do not have the means or authority to enforce truck parking near the port but they want to address the concerns of the city.

The expert believes that ports and the CHP will support the use of VWS applications to identify overweight trucks and prevent roadway and structural damage, and that owner-operated truckers will oppose this technology because it can be used to identify violators.

2.17 Interview 17

The seventeenth stakeholder/expert interview was conducted with an engineer from Caltrans WIM division. The expert provided researchers with an overview of the current WIM system and outlined several weaknesses/problems associated with the current system.

The expert informed researchers that Caltrans currently contracts with International Road Dynamics (IRD) for all WIM sites in California. IRD designed the WIM technology used in California (fixed bending plates placed in concrete) and maintains the systems once they have been built. These fixed units use a lead loop to collect speed data, two bending plates that sense the impact from the vehicle and weigh the vehicle and a trailing loop. Other sites use two loops and a Piazo to collect vehicle classification data. According to the expert, there are currently 115 WIM sites and 50 PrePass sites operating in the state of California.

When asked about the functionality of current WIM sites, the expert informed researchers that some sites work well, are reliable, accurate and never go “offline” or break down. However, the expert stated that there are several problem sites throughout the state that go “offline” and are always experiencing bending plate failures and software problems. According to the expert, these sites are located in areas where there are extreme pavement conditions, such as snow, extreme heat and high volumes of traffic. The expert stated that software problems are usually easy to fix, but when a bending plate failure occurs, the roadway usually has to be closed down and the concrete has to be removed in order for engineers and maintenance crews to fix the problem. The expert stated that this is very expensive and difficult to do in high traffic areas such as LA County. According to the expert, this process has to be repeated in certain problem locations over and over again.

The expert informed researchers that there is one type of bending plate called a “Kistler” plate which does not have to go into concrete but can be placed in asphalt. This reduces the maintenance time and costs associated with repairing damaged plates. These plates are currently being used at the Port of Long Beach and have yet to have any problems handling the high truck volume. The expert recommended that researchers examine the types of technologies used in Florida because Kistler contracts with the Florida Department of Transportation.

The expert stated that designing and building WIM sites with greater longevity, less bending plate failures and loop card errors would decrease the costs associated with maintaining the current system.

When asked about who (which agencies) would support and oppose the use of VWS technologies, the expert informed researchers that her experience with the CHP had led her to believe that they are frustrated with the maintenance of WIM sites and that when the sites break down or go “offline,” the CHP is unable to screen vehicles and this leads to friction between Caltrans and the CHP.

The expert was also asked about other VWS technologies (i.e., security applications, emissions sensing technology, and electronic credentialing). The expert informed researchers that her area of expertise is limited to IRD technology and she did not feel comfortable answering questions about other VWS applications.

2.18 Interview 18

The eighteenth expert/stakeholder interviews were conducted with two experts from the California Air Resources Board (CARB) Mobile Sources Enforcement Division. Researchers were invited to attend a commercial vehicle strike force at the Port of Oakland with representatives from CARB, CHP and the U.S. Coast Guard. According to the experts, CARB is involved with the strike force team to identify and cite gross polluters and trucks that do not have the engine software upgrade (reflash) sticker on the engine.

The experts informed researchers that CARB does not have jurisdiction over the vehicle code and can only issue citations based on health and safety laws. However, in order for CARB to stop a truck for a road side inspection (smoke opacity test), the CHP must be present to initiate the stop.

During the strike force, researchers had the opportunity to ask the experts questions regarding emissions enforcement in California. The field supervisor informed researchers that nine two-man teams operate throughout the state of California and check for excessive smoke, dyed fuel and the reflash sticker. The field technician informed researchers that the CARB also deals with environmental justice, spends a lot of time at the Ports of L.A. and Long Beach and conducts inspections at the weigh stations as well.

The field supervisor estimated that during the two day strike force, 30-40 citations would be issued for emissions violations, including excessive smoke and non-compliant engine software upgrades.

According to the experts, there are three main ways to exit the Port and there are bypass roads as well. CARB and CHP block these routes and trucks are pulled over randomly. When trucks were pulled over, drivers were asked to push the accelerator for a visual smoke test. If the field technician saw what he thought was too much smoke, then a smokeometer was hooked up to the truck and a smoke opacity test was conducted.

During the strike force, researchers observed the CARB pull over 25 trucks. Out of this number, seven truck drivers were issued citations for a lack of a reflash sticker. No truck drivers were cited for dyed fuel and one was cited for excessive exhaust. Violations are given to the owner of the truck, which is usually the driver. However, if the truck belongs to a fleet or the driver is not the owner; the citation is given to the driver but issued to the truck's owner through the mail. According to the field technician, the first violation for a lack of a reflash sticker is $300 and the second is $1800. The field supervisor informed researchers that CARB does not put trucks out of commission except in rare instances if citations have not been paid. The field technician stated that the only problem with the smokeometer test is that "you can't do smoke testing at night."

When asked about the accuracy and reliability of the smoke opacity test, the experts informed researchers that the smoke opacity tests runs at +/- 2% ppm. Researchers then questioned the experts about remote emissions sensing technologies. The experts agreed that this technology is highly inaccurate and that it runs at +/- 2000 ppm. The experts stated that this technology has been researched for years and that CARB cannot find a way to make it more accurate or reliable.

While on the strike force, researchers observed hundreds of trucks passing the inspection site. The experts stated that the current inspection process allows for many trucks that should be cited to bypass, but it is the best system of catching violations because the technology requires each truck be stopped for the inspection. The experts informed researchers that they can only inspect a small number of trucks and would support the use of technology to identify gross polluters and other emissions violations if the technology was accurate.

2.19 Interview 19

The nineteenth expert/stakeholder interview was conducted with a CHP officer from the Golden Gate Division's Commercial Vehicle Enforcement Unit. The officer conducts strike force inspections with CARB twice a month.

Researchers asked the expert about current commercial vehicle inspection processes in California. The expert informed researchers that the CHP does not need probable cause to stop and inspect trucks if they have not been inspected for 90 days (recorded with a sticker). The expert outlined the three types of inspections conducted in California.
The officer described Level One inspections (full inspection), which includes weighing the vehicle (with portable scales or escorting the truck to a static scale); checking the driver logbook, insurance and license; and getting under the truck to examine the frame, brakes, tires and for expired tags. According to the officer, a Level Two inspection (walk around) consists of checking the lug nuts, tires, frame and for expired tags. The expert informed researchers that the Level Three inspection (paperwork only) is the most common type, which includes checking the driver logbook, insurance, license and registration.

When asked about weaknesses/problems with the current commercial vehicle inspections/enforcement process, the expert stated that California does a good job but there are areas that need improvement. According the expert, drivers automatically take responsibility when the vehicle is taken out on the road, however, many times the companies/owners will send out drivers with noncompliant trucks. The expert feels that drivers do not have many options. According to the expert, many drivers are paid by load and must deliver to get paid. The expert thinks that drivers are often willing to engage in risky behaviors (i.e., driving an overweight truck or a truck without insurance or even bad brakes) to make money or in some cases keep their jobs.

In addition, the expert believes that there are lots of violations, but it is difficult to enforce current sanctions. For example, the expert described gross negligence (i.e., when a truck speeds 15 mph over or more) and the challenges with enforcing truck speed limits. The expert stated that "there are too many trucks on the road and not enough officers to catch all of the violators." The expert informed researchers that he used to work at a CVEF and that trucks find ways to avoid the weigh stations or wait until weigh stations fill up with trucks and then they bypass.

The officer informed researchers that strike forces and officers that work in divisions such as the one he belongs to are supposed to conduct inspections and catch violators all day. However, the expert stated that during a typical day an officer can only stop about 10 trucks.

During the strike force the officer did not set up his portable scale. Researchers questioned the officer about this and the officer responded by showing researchers how difficult it is to set up the scale because of how heavy it is. The expert stated that the portable scales used by CHP are not really mobile scales. The expert informed researchers that the scales cannot be left on the roadway, but when a truck is pulled over, the scales are placed in front of the tires and then the truck drives onto the scales for a weight reading. However, the scales have to be picked up and moved for each truck (depending upon size) and there is often a lack of safe room to accommodate and conduct the roadside weighings. The expert stated that sometimes there is nowhere to weigh the trucks with the portable scale and that a static scale is too far away. The expert stated that because the portable scale is difficult to use, many officers just focus on safety violations.

When asked about WIM technologies that could potentially be used to assist with inspections and enforcement, the officer stated that he "would support the use of any tool that can help make [his] job easier." However, the expert felt that "higher ups" may not like the use of any new technologies because the reliability and accuracy of the technology may be called into question.

The expert also stated that he thinks it is important for officers to make traditional roadside stops to check for driver fatigue, DUIs and drivers that are on stimulant drugs. The expert spoke of once instance where he witnessed a truck almost crash. When the officer pulled the truck over, the driver had a blood alcohol level of .20. According to the expert, the limit is .04 for commercial drivers.

Researchers asked the expert about locations where he might support the use of VWS technologies. The expert stated that he thinks this technology should be used as a screening tool prior to trucks arriving at CVEF. The expert thinks that VWS technologies can be used to help officers categorize which types of inspections should be conducted on particular trucks. The officer emphasized that officers working with trucks can look at a truck and tell if the truck is overweight just by the way the tires sag. However, the officer is open to the use of any technologies that can help officers streamline the system.

During the strike force, researchers observed the expert pull over seven commercial vehicles and conduct three level two inspections and four level three inspections. During these inspections the expert encountered a driver with inconsistencies in his logbook and another truck that was thought to be stolen due to a lack of registration and paperwork. Interestingly, the expert initially did not want to put the truck out of service because the expert stated that "calling a truck that can pull a diesel truck is a hassle." Researchers observed two CHP officers discuss what to do with the truck and they decided to put the truck out of service. When researchers questioned the expert about what would happen to the driver, the expert informed researchers that the driver would have to pay the towing and storage fees and provide registration and proof of insurance before he could get his truck back.

2.20 Interview 20

The twentieth expert/stakeholder interview was conducted with a Branch Chief from the U.S. Coast Guard Intermodal Inspections Division, governed by the Department of Homeland Security. According to the expert, the U.S. Coast Guard works closely with the CHP and U.S. Customs to conduct commercial vehicle container inspections. This branch of the Coast Guard (Intermodal Inspections) works with the CHP at least once a month on strike force roadside inspections outside of the Port of Oakland. According to the expert, the Coast Guard does not have jurisdiction over commercial trucks but the containers by which cargo is transported.

According to the expert, a typical truck inspection includes an examination of the container frame and the container. Containers that are found to be structurally unsafe because of bends, holes or any other damage are banned from being placed onto a ship. The Coast Guard places a notification sticker on any banned containers and fines can be assessed if other divisions of the Coast Guard find the container on a ship. The fines are given to whoever moves the container. The expert informed researchers that the ports usually contract with container moving companies and that it is very difficult to find out who actually moved the container, making it difficult to enforce fines. According to the expert, citations range from $2,000-$30,000.

When asked about problems/weaknesses with the current commercial vehicle inspection process, the expert outlined what he described as limitations in enforcement policies. The expert stated that the Coast Guard has limited jurisdiction in cargo container inspections and can only inspect as far as the first tier of dunnage or 3 feet in a cargo container. According to the expert, the Coast Guard must work closely with U.S. Customs when a more in-depth inspection is required. The expert informed researchers that U.S. Customs has authority to search any container.

According to the expert, the Coast Guard tries to inspect every container marked with a hazardous materials sticker. However, the expert stated that a lack of resources, including manpower, limits the Coast Guard's ability to search every container that comes in and out of the ports. The expert feels that the emphasis is often placed on containers carrying exports and he feels that resources should be used to inspect goods coming into the country instead. In addition, the expert stated that there is a huge problem with hazardous materials not being properly marked. He provided researchers with an example of an inspection where he found ammonia phosphorous and fertilizer. According to the expert, these were the materials used in the Oklahoma City bombing. The expert stated that the driver was oblivious to the fact that he was driving with something that was essentially a truck bomb.

When asked about VWS technologies that could potentially be used for screening purposes, the expert stated that he would support the use of any technology that could assist with screening and inspections. The expert showed researchers a new piece of technology called a laser range finder. The expert stated that this device is used to find hidden panels placed in containers to smuggle drugs, money and weapons. The expert emphasized the importance of inspections and the limited resources available to conduct such inspections. The expert feels that the U.S. is vulnerable to terrorist attacks due to the lack of cargo inspections and because goods movements are not adequately tracked.

APPENDIX F

Current Distribution of Commercial Vehicle Travel in California

PATH TO 6105

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California Department of Transportation 2004 average daily truck traffic counts (ADTT) were evaluated to identify locations with high volumes of truck travel. Sites with average daily truck volumes over 20,000 are listed in Table 1 below. The average daily traffic volume (across all traffic count sites) is 4,254, with a standard deviation of 5,909.

Table 1. Routes with High Truck Traffic Volumes

Route	Site Description	District	County	ADTT	% of Total Traffic
5	JCT. RTE. 205 WEST	10	SJ	38808	26.4
710	JCT. RTE. 105	7	LA	38272	16.86
710	LONG BEACH, JCT. RTE. 91, ARTESIA FREEWA	7	LA	37888	17.38
605	SANTA FE SPRINGS, JCT. RTE. 5, SANTA ANA	7	LA	37700	14.12
710	JCT. RTE. 105	7	LA	37417	15.99
710	FIRESTONE BLVD	7	LA	36550	17
605	WHITTIER, JCT. RTE. 72, WHITTIER BOULEVA	7	LA	36147	14.12
605	WHITTIER, JCT. RTE. 72, WHITTIER BOULEVA	7	LA	36006	14.12
91	LONG BEACH, JCT. RTE. 710, LONG BEACH FR	7	LA	35930	14.09
605	JCT. RTE. 60, POMONA FREEWAY	7	LA	35865	14.12
91	BELLFLOWER, LAKEWOOD BOULEVARD (JCT RTE	7	LA	35084	14.09
91	CERRITOS, JCT. RTE. 605, SAN GABRIEL RIV	7	LA	34380	14.09
91	BELLFLOWER, LAKEWOOD BOULEVARD (JCT RTE	7	LA	33534	14.09
5	STOCKTON, JCT. RTE. 4	10	SJ	33120	24
710	COMMERCE, JCT. RTE. 5, SANTA ANA FREEWAY	7	LA	32895	14.62
605	JCT. RTE. 105	7	LA	30913	10.27
5	STOCKTON, JCT. RTE. 4	10	SJ	30135	24.5
5	STOCKTON, JCT. RTE. 4	10	SJ	30080	23.5
99	JCT. RTE. 58 WEST, JCT. RTE. 178 EAST	6	KER	29820	21
10	ONTARIO, JCT. RTE. 15	8	SBD	29766	12.1
99	JCT. RTE. 58 WEST, JCT. RTE. 178 EAST	6	KER	29150	27.5
605	JCT. RTE. 60, POMONA FREEWAY	7	LA	27890	11.97
880	OAK/MADISON STREETS	4	ALA	27713	10.7
60	CENTRAL AVENUE	8	SBD	27662	12.24
60	CENTRAL AVENUE	8	SBD	27662	12.24
60	ONTARIO, JCT. RTE. 83	8	SBD	27662	12.24
605	BALDWIN PARK, JCT. RTE. 10, SAN BERNARDI	7	LA	27651	11.97
5	FRENCH CAMP OVERCROSSING	10	SJ	27500	25
60	LOS ANGELES/SAN BERNARDINO COUNTY LINE	8	SBD	27418	12.24
60	ONTARIO, JCT. RTE. 83	8	SBD	27418	12.24
710	LONG BEACH, JCT. RTE. 91, ARTESIA FREEWA	7	LA	27197	14.39
5	JCT. RTE. 120 EAST	10	SJ	27195	25.9
60	GROVE AVENUE	8	SBD	27050	12.24
710	DEL AMO BOULEVARD INTERCHANGE	7	LA	26653	14.89
5	MARCH LANE	10	SJ	26450	23
710	JCT. RTE. 405	7	LA	26130	14.68
10	ONTARIO, JCT. RTE. 15	8	SBD	26085	11.1
5	FRENCH CAMP OVERCROSSING	10	SJ	26010	25.5
10	MOUNTAIN VIEW AVENUE	8	SBD	25476	13.2
91	CERRITOS, JCT. RTE. 605, SAN GABRIEL RIV	7	LA	25280	9.26

10	COLTON, JCT. RTE. 215	8	SBD	24860	11
110	JCT. RTE. 91, ARTESIA FREEWAY	7	LA	24426	8.98
5	LINCOLN AVENUE	12	ORA	24415	9.5
880	OAKLAND, JCT. RTE. 77	4	ALA	24308	10.3
91	LOS ANGELES ORANGE COUNTY LINE	7	LA	24237	10.27
10	UPLAND, JCT. RTE. 83	8	SBD	24153	9.7
5	LINCOLN AVENUE	12	ORA	24000	9.6
10	JEFFERSON STREE/INDIO BOULEVARD	8	RIV	23725	32.5
880	JCT. RTE. 238 EAST	4	ALA	23545	8.5
5	KATELLA AVENUE	12	ORA	23520	9.6
710	COMMERCE, JCT. RTE. 5, SANTA ANA FREEWAY	7	LA	23488	13.27
710	JCT. RTE. 60	7	LA	23264	12.18
880	OAKLAND, JCT. RTE. 77	4	ALA	23040	9.6
10	MOUNTAIN VIEW AVENUE	8	SBD	23001	12.3
5	SUN VALLEY, JCT. RTE. 170, HOLLYWOOD FRE	7	LA	22994	7.49
5	KATELLA AVENUE	12	ORA	22990	9.5
5	JCT. RTE. 118, SIMI/SAN FERNANDO VALLEY	7	LA	22955	8.14
10	ETIWANDA AVENUE	8	SBD	22654	9.64
99	JCT. RTE. 65	6	KER	22500	30
710	JCT. RTE. 405	7	LA	22288	13.59
605	BALDWIN PARK, JCT. RTE. 10, SAN BERNARDI	7	LA	22175	11.61
5	SANTA ANA, JCT. RTES. 22 AND 57, GARDEN	12	ORA	22080	6.4
5	SYLMAR, JCT. RTE. 210, FOOTHILL FREEWAY	7	LA	22033	8.54
5	TUSTIN, JCT. RTE. 55, COSTA MESA FREEWAY	12	ORA	22016	6.4
5	TUSTIN, JCT. RTE. 55, COSTA MESA FREEWAY	12	ORA	21840	6.5
10	JCT. RTE. 30	8	SBD	21840	12
710	LONG BEACH, JCT. RTE. 1, PACIFIC COAST H	7	LA	21757	14.22
10	COLTON, JCT. RTE. 215	8	SBD	21645	11.1
10	UPLAND, JCT. RTE. 83	8	SBD	21336	8.4
10	ETIWANDA AVENUE	8	SBD	21208	9.64
10	FONTANA, CHERRY AVENUE	8	SBD	21208	9.64
605	JCT. RTE. 105	7	LA	21190	6.88
5	COMMERCE, JCT. RTE. 710, LONG BEACH FREE	7	LA	21060	9
5	STOCKTON, HAMMER LANE	10	SJ	21018	22.6
5	COMMERCE, GARFIELD AVENUE INTERCHANGE	7	LA	20854	9.31
605	CERRITOS, JCT. RTE. 91, ARTESIA FREEWAY	7	LA	20846	6.88
880	SAN LEANDRO, JCT. RTE. 112	4	ALA	20832	8.68
5	FULLERTON, JCT. RTE. 91, RIVERSIDE/ARTES	12	ORA	20664	9.35
5	SANTA FE SPRINGS, JCT. RTE. 605, SAN GAB	7	LA	20657	8.79
580	JCT. RTE. 84	4	ALA	20496	12.2
880	JCT. RTE. 238 EAST	4	ALA	20496	8.4
10	JCT. RTE. 30	8	SBD	20400	12
5	LOS ANGELES, JCT. RTE. 60; GOLDEN STATE	7	LA	20328	7.7
10	JEFFERSON STREE/INDIO BOULEVARD	8	RIV	20280	33.8
5	ESPERANZA STREET	7	LA	20117	7.62

In Figures 1 to 9 below, specific sites with high truck volumes by county and roadway are illustrated by maps.

Figure 1. Route 99 in Kern County.

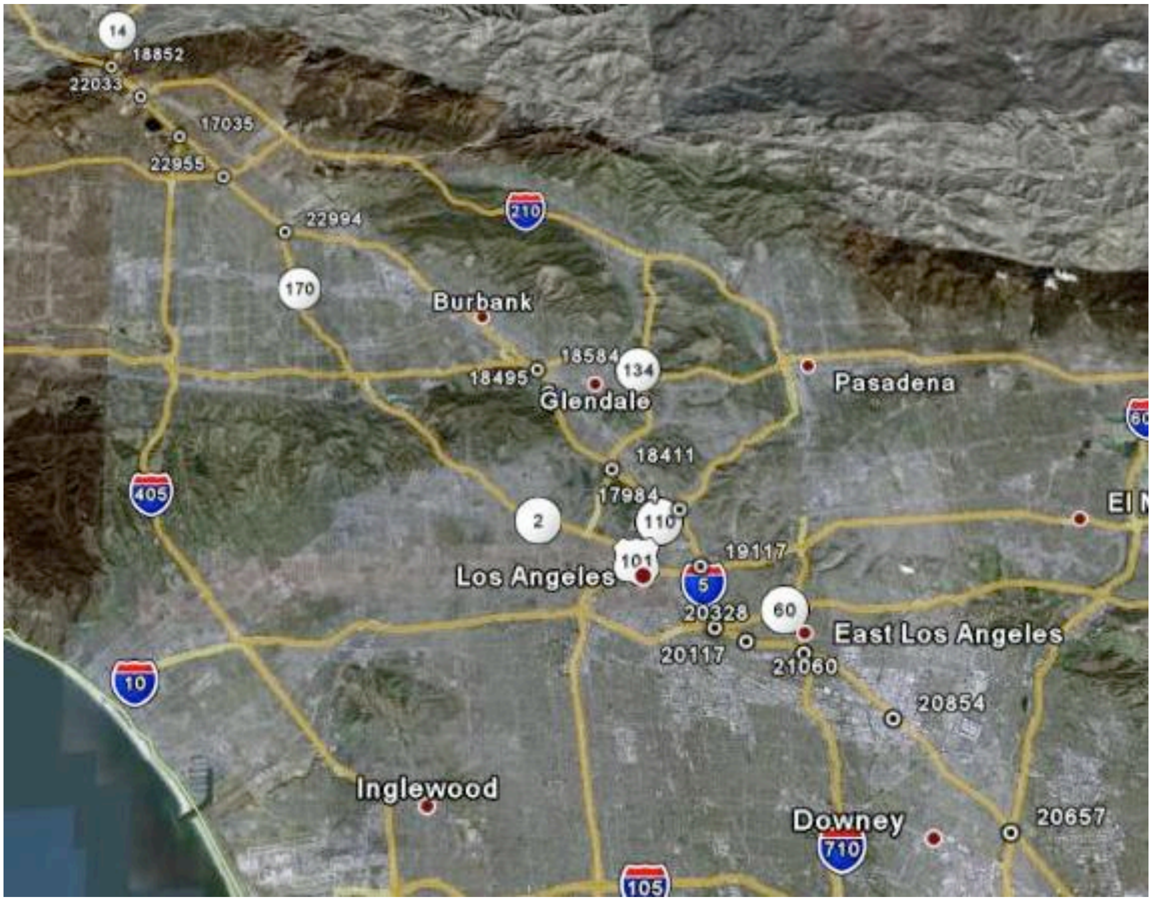

Figure 3. 91, 605, and 710 in Los Angeles County.

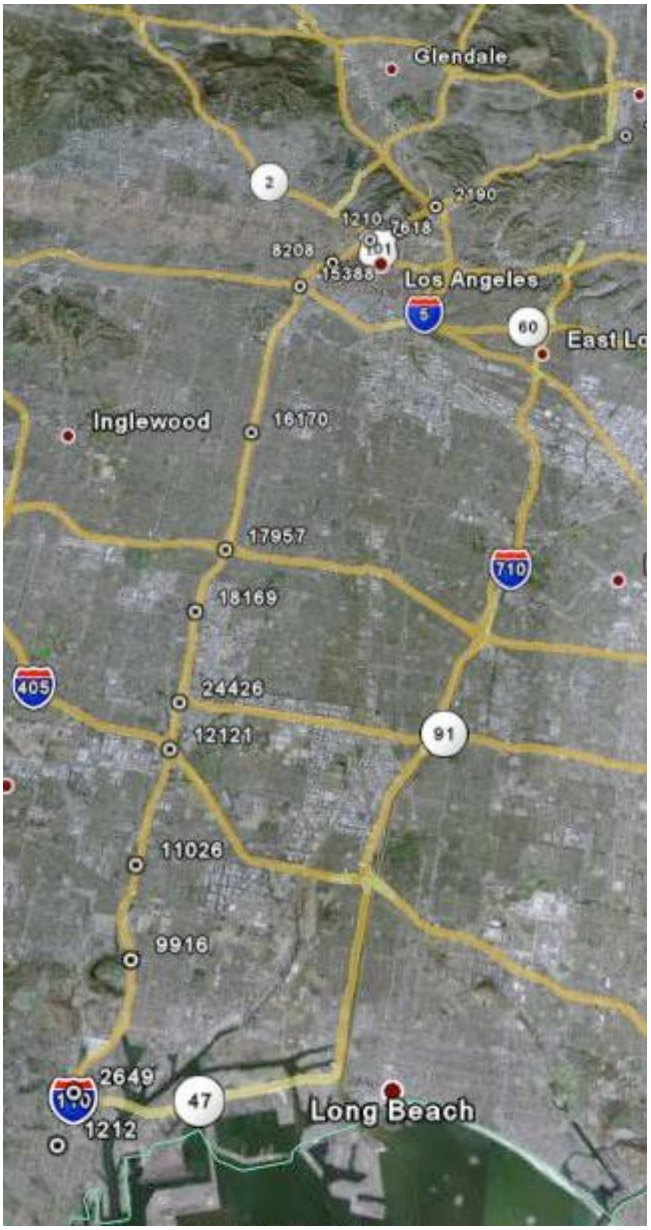

Figure 4. 110 in Los Angeles County.

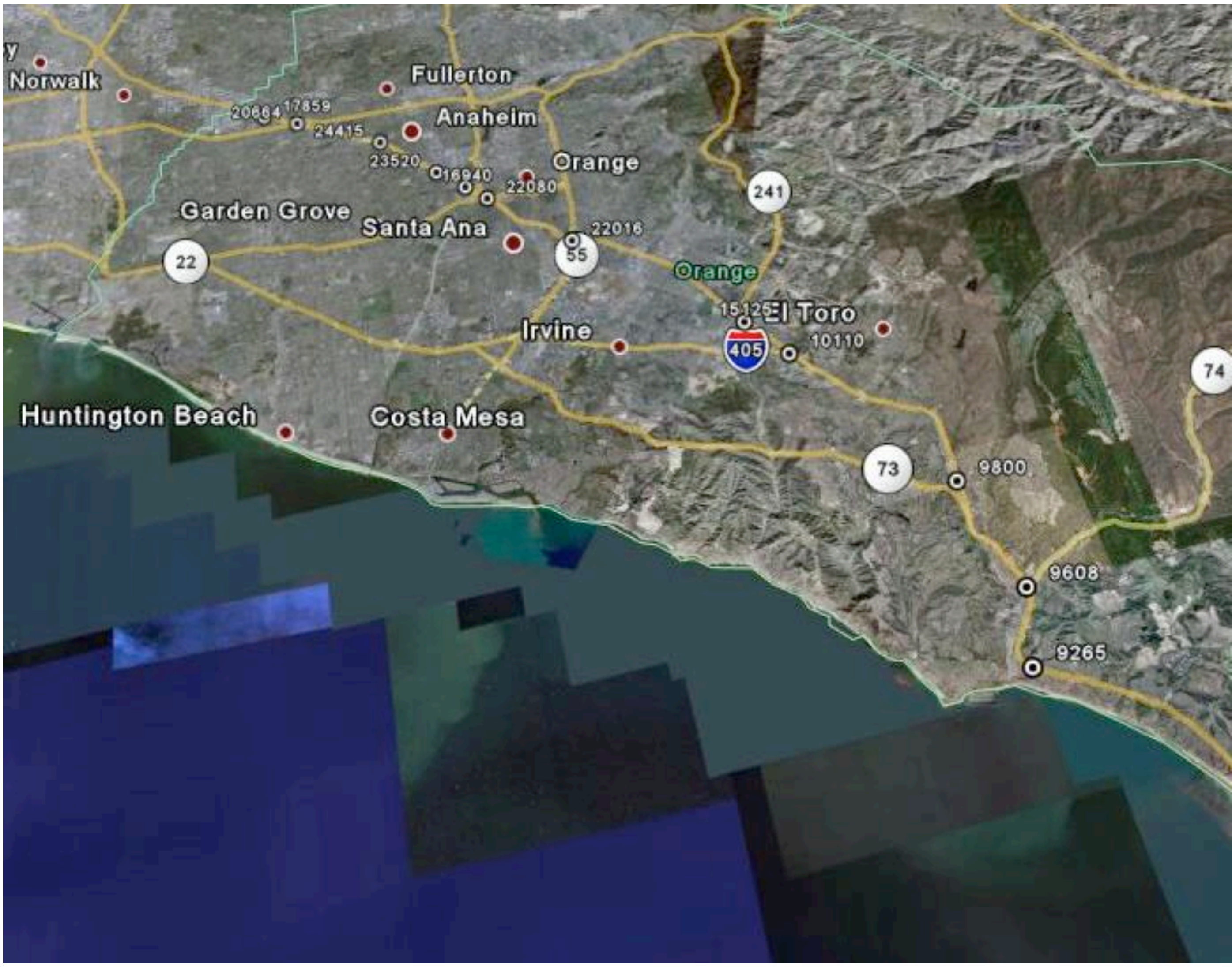

Figure 5. I-5 in Orange County.

Figure 6. Route 10 in Riverside.

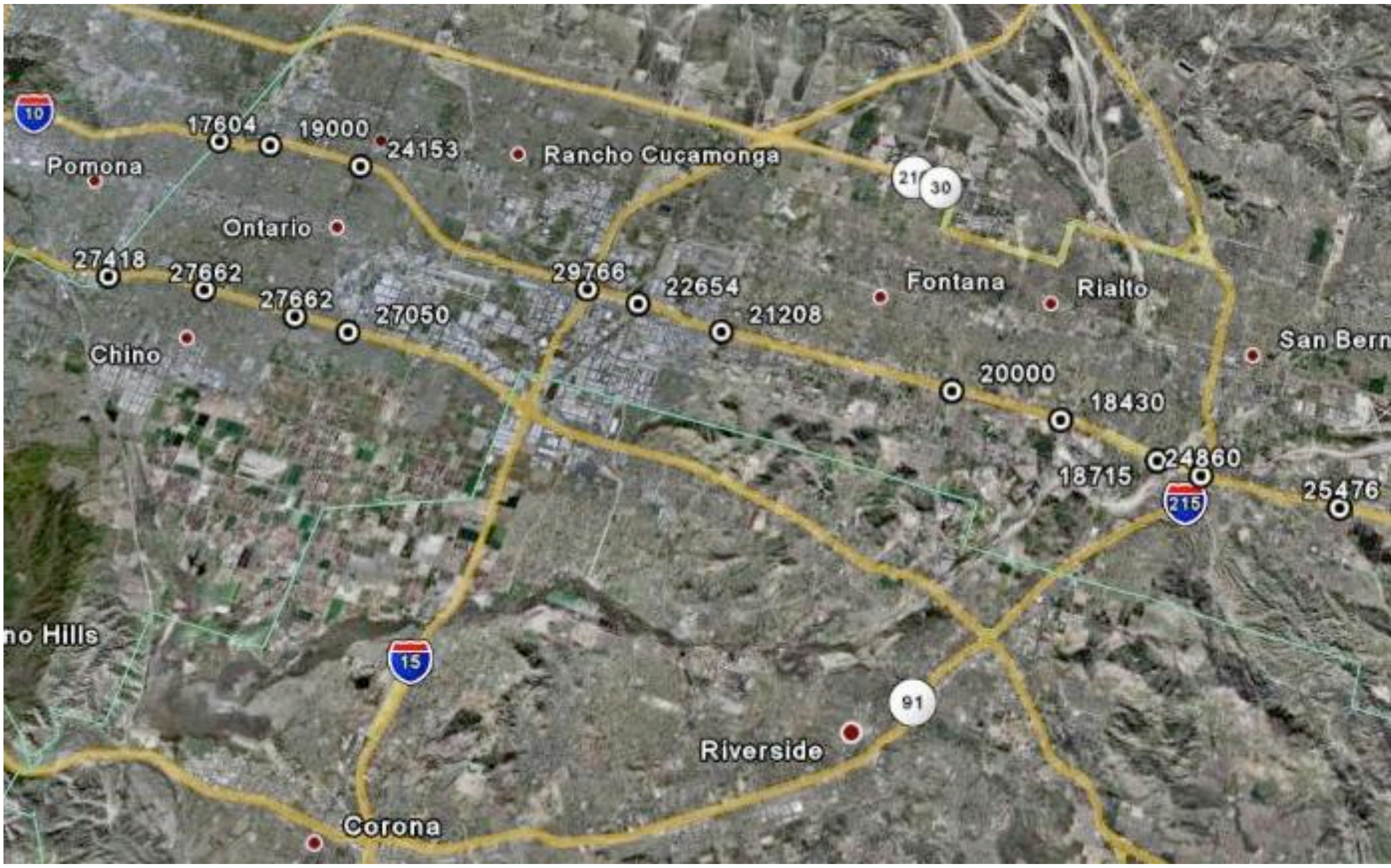

Figure 7. Route 10 and 60 in San Bernardino.

Figure 8. I-5 in San Joaquin County.

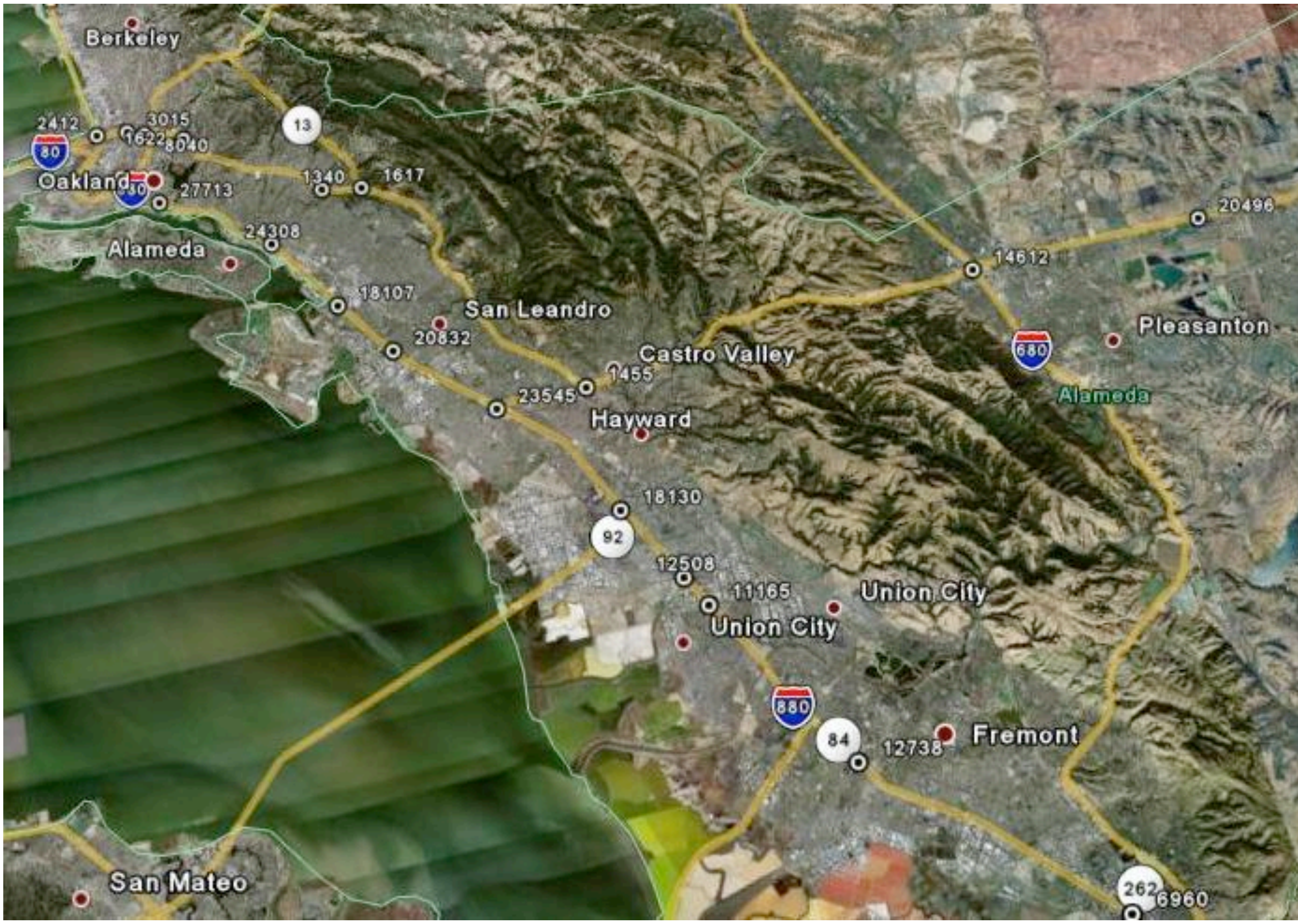

Figure 9. 510 and 880 in Alameda County.

APPENDIX G

Technical Evaluation: Safety, Security and Air Quality Screening and Inspections Applications

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1: PROJECT INTRODUCTION AND REPORT ORGANIZATION

This report reviews commercial vehicle related technologies that can be used for safety, security, and air quality screening and inspections on U.S. Highways. These largely fall into two categories: technologies used to identify commercial vehicle operators relative to their operating history and those used to detect problems with vehicles and cargo. These technologies are in various stages of development, from the drawing board to widespread implementation in both California and the U.S. Many of the technologies reviewed as part of this evaluation have overlapping applications in the areas of safety, security and air quality.

2: COMMERCIAL VEHICLE INFORMATION SYSTEMS AND NETWORKS (CVISN)

The Commercial Vehicle Information Systems and Networks (CVISN) provide a standard for communication technology and information systems among commercial vehicle carriers. CVISN aims to streamline and automate safety checks, identification, and regulation of commercial vehicles by using technologies that improve efficiency. The three main components of CVISN are Safety Information Exchange, Electronic Credentialing, and Electronic Screening (SIE, 2002, p.1-1).

2.1 Safety Information Exchange (SIE)

Safety Information Exchange (SIE) systems are used to exchange and process safety data and safety credentials information for vehicles, drivers, and carriers involved in commercial vehicle operations (SIE, 2002, p.2-1). Safety information is used by government agencies to assess safety performance and implement necessary regulation or training of carriers to improve overall safety. Automated data collection ensures equitable analysis of all operators and focuses government resources on operators who have proven to be unsafe or are determined to be high-risk. The two main systems that facilitate data exchange are SAFER and CVIEW.

2.1.1. Safety and Fitness Electronic Records System (SAFER)

SAFER is a communications system developed by the Federal Motor Carrier Safety Administration (FMCSA) to provide accurate and updated commercial vehicle safety and credential information via standardized “snapshots” of carrier, vehicle, and driver information. State safety inspectors at administrative centers download these snapshots using software applications called ASPEN and the SAFER Data Mailbox (SDM). Aspen is used to upload carrier information to state systems, while SDM temporarily stores the data (SIE, 2002, p. 3-12).

2.1.2. Commercial Vehicle Information Exchange Window (CVIEW)

CVIEW is fundamentally the same as SAFER, utilizing a similar network and database to achieve the same safety and screening objectives as SAFER, but on the state level. Similar to SAFER, CVIEW creates and stores snapshots of state vehicles and is responsible for making these snapshots available to state agencies (SIE, 2002, p.3-3). CVIEW is also responsible for updating SAFER with data from state inspection sites and any other state-implemented systems. By updating the SAFER database with any information entered through CVIEW, individual states are ensured of having all the necessary information about commercial vehicles, regardless of their state of origin or screenings in other states. An example of the information stored in a SAFER/CVIEW snapshot is provided below.

Figure 1

Snapshot Data Stored in SAFER/CVIEW

Data → ↓Snapshot	Identifier/Census Data	Safety Information	Credential Information
Carrier	● [1]Primary Carrier ID; ● Other IDs (e.g., Taxpayer ID, DUNS, IRP account, etc.); ● Names; ● Addresses; ● Type; ● Operations Characterization	● Safety Ratings; ● Accident, Inspection & Violation Summaries; ● Safety Review History; ● [1] Last OOS; ● PRISM Data	● Carrier Registration; Fuel Tax Data; ● Insurance Data; HazMat Registration; [1]Permit Data; Electronic Screening Enrollment; Carrier Check Flags (e.g., IRP & IFTA flags)
Vehicle	● [1]VIN; ● [1]Vehicle Plate ID Other IDs (e.g., Plate, IRP Account, CVIS Default Carrier, Transponder, Title Number); Vehicle Description	● Last Inspection Overview; ● Inspection & Violation Summaries; ● [1]Last OOS; ● CVSA Decal Data; PRISM Data	● Apportionment (i.e. Cab Card Data); [1]Permit Data; Electronic Screening Enrollment; ● Vehicle Check Flags (e.g., Registration Check Flag)
Driver (Future)	[1]Driver Unique ID; [1]Home State; Names; Address; DOB, Sex; Citizenship	Last Inspection Overview; Accident Summary; Inspection & Violation Summaries; [1]Last OOS	Driver Check Flags (e.g., DMV Check Flag)

● As of April 2001, fields populated in the SAFER database for interstate
Note: 1 = Data are current; all other data are historical

(SIE, 2002, p.4-5)

2.2 Electronic Credentialing

As shown in figure 1, SAFER/CVIEW snapshots contain safety information as well as credential information. There are various credentials required for operating a commercial vehicle that are handled electronically, including operator registration, vehicle title, liability insurance, payment of fuel taxes, as well as applications for and issuance of oversize/overweight and hazardous materials permits (CA, 2000, p.2-1). Both carriers and state agencies use software to submit and collect applications and payments. Electronic credentialing systems change the incentive structure surrounding credential administration for commercial vehicle operators and carriers. By essentially "piggy-backing" on the same systems used for SIE and electronic screening, electronic credentialing systems are essentially costless, assuming that SIE and screening continue. Automatic checks of credential information means more time wasted for offenders and more time saved for carriers that comply with tax requirements and other regulations.

2.3 Electronic Screening

Electronic screening is a "selection mechanism" by which weigh-station and inspection resources target high-risk operators with the aim of improving safety and traffic flow, reducing costs, and lowering emissions by requiring few decelerations (ES, 2002, p.2-1). Allowing trucks with good safety records to bypass inspections improves efficiency for carriers and weigh stations, provides incentives for operators to have good safety records, and encourages enrollment in electronic screening programs. Automated Vehicle Identification (AVI) is the term for how commercial vehicles are identified on the roadside. Using various transponder technologies in conjunction with SAFER/CVIEW systems, drivers transmit their identification information and screening history to roadside stations and await the bypass signal. Electronic screening systems work at mainline speeds and enable fewer stops and waste less fuel and time. Currently, there are three major electronic screening enrollment (ESE) programs in the United States: HELP/PrePass, NorPass and Oregon Greenlight (gives out transponders for free). Fees are then collected based on the independent fee structures of each program. One major issue surrounding electronic screening programs is interoperability between programs such as PrePass, NorPass and Green Light (Bell, 2001, p.26). Interoperability has shown improvement in Oregon, however, as Green Light transponders have now been approved by PrePass clearance stations (Green Light, 2006).

2.3.1. Heavy Vehicle Electronic License Plate (HELP/PrePass™)

PrePass™ is the most widespread ESE program in the U.S., operating in 25 states nationwide with more than 386,000 trucks enrolled by September 2006 (prepass.com). PrePass™ organizes pre-enrollment safety and credentials checks, as well as routine updates of safety and screening information. PrePass™ also provides transponders at no up-front cost to carriers. Cost per vehicle is $15.49 per month, according to a PrePass™ sales representative.

2.3.2. Radio Frequency Identification (RFID)

RFID is the name given to a collection of technologies that use radio frequencies as a means of identification. RFID technologies fall into two categories: active and passive. Passive RFIDs are low cost, short range and disposable, drawing on radio waves from the reader to supply itself with power (Wolfe, 2002, p.5). The disadvantages of passive RFIDs include their short broadcasting range (only a few feet) and that the tag can be read for a very long time, even after the product is no longer being tracked. Active RFIDs use a battery and an antenna to transmit more information at a greater distance, greatly increasing their signal strength (Wolfe, 2002, p.6). RFID technologies have various applications in transportation safety and security, including tracking, tamper detection and vehicle-roadside communications. RFID technologies are widely used in electronic seals (E-seals), allowing products to be tracked accurately and in real-time without human intervention or error (Bronzini, 2004, p.8). RFID has been applied to hazardous materials tracking and tampering, as well as border crossings with the Secure Electronic Travelers Rapid Inspection (SENTRI) on the Mexican border and the NEXUS program on the Canadian border (Kain, 2006, p.4). RFID is also used at weigh stations to transmit size, weight, registration and other safety records, as well as to receive information from roadside sensors monitoring tire and brake conditions. Security risks arise with the use of RFID, as the technology allows anyone with the proper equipment to identify items as potential targets of theft or tampering.

2.3.3. Dedicated Short Range Communications (DSRC)

DSRC is the name given to an emerging communications technology that has various applications in transportation and other industries. DSRC is essentially a sub-set of RFID; it uses radio frequencies to transmit large amounts of information. New 5.9 GHz DSRC consist of roadside units and on-board units, which facilitate communication between roadside stations and vehicles as well as between vehicles themselves, at speeds up to 120 mph and with range up to 1000 meters (Roebuck, 2005, p. 4). On the road, DSRC transponders or "tags" are used to facilitate communication between commercial vehicle operators and roadside inspection stations. The tag identifies the truck and sends credential and safety information to the roadside station, where it is determined whether the truck gets the "bypass" signal or the "pull-in" signal. Used in conjunction with other weigh-in-motion technologies and databases, DSRC allows commercial vehicles to communicate all necessary information to roadside stations without stopping and thus saves fuel and time for carriers. DSRC increase the reliable range of roadside-vehicle communication, providing commercial vehicle operators further incentives to enroll in pre-clearance programs (Roebuck, 2005, p.4).

2.3.4. License Plate Readers (LPRs)

Automated license plate reading technology uses a camera generally mounted on a streetlight to create an image of a license plate. Then, optical character recognition (OCR) software is used to automatically translate the picture into letters and numbers (Cicarelli, 2006, p.4). One major concern with LPRs is the truncation of plate numbers, where the first and fourth characters are eliminated from all plates. A major evaluation of LPRs, conducted by the Innovative Data Collection (IDC) research project, concluded that LPRs were effective at reading the license plates of passing vehicles. Using "off-the-shelf" equipment that had not been specifically redesigned to read Florida plates, IDC was able to produce character recognition rates of greater than 50 percent (Cicarelli et al, 2006, p.11). These tests were conducted on major interstate highways and other arterials, though no mention was made of the speeds at which tests were conducted. Additionally, while recognition rates were adequate, readings were only taken of a maximum of 60.2 percent of the stream of traffic, suggesting that as traffic volume increases, accuracy and coverage of LPRs may decrease.

3: BRAKE SCREENING

3.1 Infrared Inspection System (IRISystem)

The IRISystem is a mobile device that can be used at roadside sites, preferably where vehicles apply their brakes IRISsytem uses a van-mounted infrared camera in conjunction with a typical color camera to produce a thermal image of the commercial vehicle's wheelbase that can be compared with the color image. These thermal images show relative temperatures of wheels when the vehicles' brakes are applied, as it approaches a weigh station. Functioning brakes get hot and appear white to the infrared camera, while non-functioning brakes appear dark (Christiaen et al, 2000, p.vii). The IRISystem camera can be removed from the vehicle for storage, if necessary. A FMCSA study (2000), conducted in four states: Georgia, Kentucky, North Carolina, and Tennessee, found that the IRISystem could be used effectively to identify problematic brakes. Over the year long study, 68 percent to 76 percent of wheels identified as problematic by IRISystem were indeed defective as confirmed by further inspection (Christiaen et al, 2000, p.21). These results were based on screening of vehicles with a maximum of 35 to 40 mph and an average of 10 mph, with only experienced operators collecting meaningful data at higher speeds. Though mainline speed (greater than 55 mph) testing was attempted, but no useful results were recorded (Christiaen et al, 2000, p.21). Operators noted that mainline screening is somewhat unpractical. Problems include identifying target vehicles, observing all wheels in a short period of time, and tracking-down vehicles once they have been identified (IRIS, 2000, p.8). One additional problem with mainline speed brake inspection is that as vehicle speed increases, the necessary distance between the vehicle and the IRISystem increases to allow operators time to complete an inspection (Christiaen et al, 2000, p.20). An Arkansas study comparing IRISystem and another infrared brake detection system reported the cost of IRISystem as $296,000 (Corbitt et al, 2002, p.8).

3.2 Raytheon NightSight ProtectIR 4000B System

This system was conceived and compared with the IRISystem by the Arkansas Highway and Transportation Department (AHTD). Similar to the IRISystem setup, an infrared camera mounted on the rooftop of an AHTD vehicle was used to take thermal images of commercial vehicles as they applied their brakes to slow for weigh stations. The Raytheon system was found to be successful in identifying failing brakes, though it was not recommended for implementation (Corbitt et al, 2002, p.7). As compared to the IRISystem, the Raytheon system did not provide a comfortable workspace for long periods of time and did not provide adequate evidence for Arkansas Highway Patrol (AHP) (Corbitt et al, 2002, p.7). The hand control for the Raytheon system does not have manual zoom or focus and only tracks at a fixed speed, making it difficult to track vehicles with changing velocity. Additionally, the Raytheon system does not have a secondary color camera and VCR setup, making it difficult to meet AHP needs for enforcement. Despite these shortcomings, the Raytheon system costs only $40,768, allowing much room for improvement before approaching the cost of the IRISystem (Corbitt et al, 2002, p.8). Both systems require trained and experienced operators to be effective at any speed exceeding 10 mph. Mainline screening was not attempted with the Raytheon system.

4: HAZARDOUS MATERIALS

Especially since the September 11 attacks, hazardous materials transportation has become an increasingly important homeland security issue, demanding technological solutions. Various solutions have been at least tested or in some cases implemented, including advanced identification and tracking technologies as well as separate technologies that detect the presence of potentially hazardous materials. Transportation of hazardous materials begins with an extensive permitting process with the FMCSA, which includes background checks for carriers, pre-trip inspections and written plans for routes and communication between driver and carrier (FMCSA-97-2180, 2004). Beyond that, carriers implement their own tracking methods and government agencies rely on roadside inspection and electronic screening to track hazardous materials.

4.1 Vehicle and Asset Tracking

There are numerous vehicle and asset tracking solutions available to commercial vehicle operators, including satellite and terrestrial triangulation and GPS-based locators. Asset tracking units often include sensors or locators directly attached to products or other assets, whereas vehicle tracking devices become a part of the vehicle. Key players produce both asset tracking and vehicle tracking devices.

Costs of tracking units have been reported in the range of $150 to $4000 including installation (Williams et al, 2004, p.C-3). More expensive tracking solutions integrate many different sensors and locators, raising both the price of hardware and the labor cost of installation. Monthly services fees are also incurred, ranging from $5 to $50 per month, with satellite services costing more than terrestrial services. The more expensive of these units are generally used for tracking construction equipment and are generally not applicable to hazardous materials tracking. These forty-six companies represent sixty-one products in the vehicle and asset tracking industry in 2004:

- Advanced Productivity Computing
- Aeris.net
- Aether Systems, Inc.
- Air IQ, Inc.
- AirLink, Inc
- AtRoad
- Avel-Tech
- Burdilla Lanser Technologies LLC
- Cabit Systems
- Cheetah Software Systems
- Cloudberry Wireless Services
- CSI Wireless
- EarthTRAK
- Fleetilla
- GE TIP
- Global 2-Way
- GPS Management
- Ida Corporation
- Insight USA
- InterTrak
- IRD, Inc
- Lorantec Systems, Inc.
- Metler Toledo
- Minor Planet
- Mobilearia, Inc.
- Network Innovations
- Northwest Nuclear, LLC
- Orbcomm
- Pana-Pacific
- PeopleNet Communications Corporation
- PowerLoc Technologies, Inc.
- Qualcomm
- Safefreight Technologies
- Sage Quest
- Satellite Security Systems of North America
- Telemisphere LLC
- TeleTouch
- Telogis
- TrackStar
- Transcore
- Trimble
- Vericom Technologies
- Vistar
- V-TRAC Systems, INC
- Waveburst Communications, Inc.
- Xata

(Williams et al, 2004, p.C-6)

This study found that the most widely used form of tracking technology was a simple cellular phone, with 80 percent of carriers equipping their drivers with a cell phone. Satellite communication devices were used by nearly 40 percent of carriers and vehicle tracking systems of some form were used by nearly 30 percent of carriers (Williams et al, 2004, p.15).

4.2 Biometrics

Biometrics is the use of biological measurement as a tool for identification and authentication. Biometric technologies have security applications for commercial vehicle operation, including proper identification and verification during transfer of goods from shipper to carrier as well as in-transit verification and anti-hijacking. Current biometric devices developed for use in commercial vehicles range from fingerprinting to retinal or facial recognition. Use of small credit card-sized devices equipped with a microprocessor called "smart" cards to hold carrier and driver information aids in biometric identification, requiring drivers to pre-register with the provider's system. Drivers using biometrics are to perform verification for shippers before taking control of shipping materials. This ensures secure transfer of hazardous materials or other goods (Williams et al, 2004, p.46).

Information available on the cost of biometric devices reported a range from $6 to $1,200, with an average cost of $1,000 per unit (Williams et al, 2004, p.C-4). The $6 component is a simple fingerprint reader that must be part of a greater system, whereas complete systems run around $1,000. Most systems can be used or are required to be used with smart cards, and unlike tracking systems, do not require installation or monthly service fees. Major players in the development of biometrics include:

• AcSys Biometrics Corporation • ActivCard • AuthenTec • Biocentric Solutions Inc. • Bioidentix • Bio-Key International • Cogent Systems • Compu-Trol Technologies Inc. • Cross Match Technologies, Inc.	• Cyber Sign Inc. • Data Management Inc. • Digital Persona, Inc. • exResource • FingerSec • Hectrix • Identix • Saflink Corporation

(Williams et al, 2004, p.C-3)

Though biometric devices are not widely deployed among commercial vehicle operators, they provide an often necessary security measure for hazardous material transport at a relatively low cost.

4.3 E-Seals

Traditionally, commercial vehicle loads are secured in a container by a manual seal, which indicates whether the container has been opened and tampered. Although traditional seals indicate the security of the container, they tell nothing of logistics such as when, where, and by whom the container was sealed or last inspected. Electronic seals or e-seals use RFID technology combined with traditional physical seals to provide this information. These E-seals have security applications relevant to hazardous material tracking. E-seal technology requires a driver to place seals on all proper cargo containers and then electronically seals each one, allowing the carrier to view seal status online.

The most widely deployed type of electronic seal uses RFID technologies, allowing information to be read from moving vehicles in a fraction of a second (Bronzini et al, 2004, p.8). As discussed before, passive and active RFIDs have very different characteristics. Since passive RFIDs must be read from a very close distance, collecting data from passive e-seals while in transit is not feasible. While passive RFID seals cost in the range of single digits dollars, seals utilizing GPS or other wireless technology can cost up to $1,500 (Williams et al, 2004, p.C-4). This has proven prohibitively expensive for some carriers, requiring reuse of seals until prices fall significantly.

4.4 Panic Buttons and Remote Disabling

A wireless "panic button" is a device that allows a driver to send an emergency alert message to a carrier or disable the vehicle (Williams et al, 2004, p.57). These devices are used in conjunction with remote disabling devices that allow the carrier to remotely disable the vehicle in the case of a hijacking or other security emergency. Together, these devices allow drivers to notify their carriers of emergencies and then take the proper action, including disabling the vehicle. Acting through the vehicle's on-board computer (OBC), emergency notification and disabling devices allow the driver and carrier to work in tandem to report and avoid emergencies. Cost information for these technologies was unavailable. A table of various hazard materials tracking technologies and their costs is given below:

TABLE 1. Technology Tiers

Tier (Cost)	Description
1 ($250)	Include a digital cellular phone with pickup and delivery software with on-phone/on-board directions/mapping. This option would also include on site vehicle disabling with the wireless panic remote. This would not be able to send a panic message but would give the ability to shut it down remotely. This would not include positioning until position location is turned on to national networks.
2 ($800)	Includes terrestrial communications with in-dash panic button.
3 ($2,000)	Includes satellite communications with an in-dash panic button and Global Login.
4 ($2,500)	Includes all of what is in tier 3 but adds the additional OBC. The other variant includes satellite communications with an in-dash and wireless panic button with Biometric authorization, and E-manifest.
5 ($3,000)	Includes satellite communications with an in-dash and wireless panic button with Biometric authorization, E-manifest and an additional OBC. The other variant is swapping the OBC for an untethered trailer-tracking device.
6 ($3,500)	Includes satellite communications with an in-dash and wireless panic button with Biometric authorization, E-manifest and E-Seals.

(DeLorenzo et al, 2003, p. 8)

4.5 Hazardous Materials Detection

Beyond the current carrier-oriented hazardous materials tracking systems in place, technologies that aim to detect potentially hazardous materials inside commercials vehicles are emerging. These technologies utilize radiation detection devices, gamma-ray radiography or x-ray systems to indicate the presence of potentially hazardous materials. Deployment of radiography devices has largely been centered on international ports of entry, most commonly inspecting containers before they leave the port.

4.6 Vehicle and Cargo Inspection System (VACIS)

Developed by Science Applications International Co. (SAIC), VACIS is a non-intrusive imaging system that uses gamma rays to create images of cargo containers. This system can either be stationary or mounted within a truck for more flexible and mobile inspection of cargo containers. VACIS has been used to inspect trucks at border crossings by the United States Customs Service since 1997, providing Customs and Border Protection officers with a tool that allows them to inspect without opening or entering cargo containers (LANL, 2000, p.1). While SAIC does not report the costs of its systems, other reports put the cost of each system around $1,500,000 (Midwest, 2005, p.7). This high cost may prove prohibitive for some applications. Applications of non-intrusive imaging include searching for contraband within cargo containers, including but not limited to illegally trafficked drugs, weapons or people. Issues surrounding the use of radioactive sources are widespread, and include proper storage and shielding from radiation.

4.7 Identification and Monitoring of Radiation in Commerce Shipments (IMRicS)

Radiation detection systems are largely still under development, with few instances of implementation. Radiation detection systems have generally been deployed at static scales, allowing time for inspection to be completed. Commercial vehicles pass through radiological sensors prior to reaching the scale, and then if sensors are tripped, alarms sound and the vehicle is subject to further inspection (Walker et al, 2004, p.7). Further development of the IMRicS system is underway at the Oak Ridge National Laboratory, in Tennessee. In 2005, Lawrence Livermore National Laboratory developed a new gamma-ray imager that can detect the energy range of interest to national security, even while the imager is in traveling (Rennie, 2006, p.7). This development suggests that there is much work to be done before radiation detection will be done at mainline highway speeds. In addition to the problem of scanning at high speeds, there is also the problem of identifying and tracking down the offending vehicle.

5: AIR QUALITY CONTROL

Emissions sensing technologies fall into two general categories: those that sense emissions on-board and those that use remote sensing to test emissions from afar. For the purposes of this investigation, we focus on remote sensing technologies.

5.1 Remote Sensing Devices (RSD)

The use of infrared spectroscopy to remotely sense vehicle emissions has developed slowly over the last 10 to15 years. The principles behind remote sensing are fairly straight forward. A light source emits a beam through the air in question and then a light-sensing device measures the difference in intensity of the light, showing the absorption of the light by trace particles in the air. Then, using knowledge of chemical compositions, the amount of target gases can be determined. Preliminary efforts to measure emissions were plagued by small sample sizes and other issues, limiting their success to detecting differences of greater than 10 percent in average emissions (Pokharel et al, 2001, p.9).

Tests carried out in Bejing provide some promising results for RSDs; however, the accuracy of RSDs depends heavily on many factors including weather, road condition, and optical alignment (Xinghua et al, 2005, p.8). Further analysis carried out by Taiwanese researchers suggests that RSD can be used to accurately identify sources of pollution (Ko et al, 2005, p.7). Additionally, research in Hong Kong focused on emissions testing of diesel vehicles with notable success, suggesting application to commercial vehicle emissions issues in the United States (Chan et al, 2005, p.2). As noted in a University of Denver study, a typical RSD that fits inside a van costs about $200,000 (Stedman, 2002, p.12).

The commercial vehicle and highway applications of RSD are still somewhat questionable. While the results presented by Chinese and Taiwanese researchers is compelling for use on both diesel-burning vehicles and regular commuter vehicles, tests were generally implemented on fixed sites such as tunnel entrances or one-lane streets. The fundamental design of RSDs limits their use to single-lane implementation. RSDs require a light beam to be emitted and then absorbed, traveling through the exhaust of a vehicle. This clearly only works across one lane of traffic, as cars driving next to each other would confound tests across multiple lanes. As such, any implementation of RSDs would necessarily be across a single lane of traffic, an on-ramp, off-ramp, toll booth entrance/exit or some other single-lane controlled environment.

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