Development and Evaluation of Alternative Concepts for Wireless Roadside Truck and Bus Safety Inspections

July 2007

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

FOREWORD

This study focused on developing and analyzing various concepts of operations that would link advanced onboard monitoring technologies with a means of wirelessly communicating such information to inspection sites in order to improve the quality and/or quantity of commercial vehicle inspections completed annually in the United States. This project is being administered by the Federal Motor Carrier Safety Administration (FMCSA) and is sponsored by the U.S. Department of Transportation's (USDOT's) Joint Program Office (JPO) on Intelligent Transportation Systems (ITS).

The work performed under the project included:

- Analysis of historical inspection and crash data to determine requirements for a wireless inspection system and a safety data message set (SDMS)
- Development of wireless inspection operational concepts defined by different wireless technologies, venues, and methodologies for collecting the data, IT support systems, and other operating and implementation scenarios
- Evaluation of the benefits of increasing levels of sophistication relative to the type and detail of diagnostic information collected from the vehicle, and of the sensors and diagnostic systems needed to support such concepts. The evaluation focused on the capital and operating costs, safety benefits, institutional issues, and deployment challenges associated with each alternative
- Development of a deployment plan for FMCSA, including a roadmap for testing, demonstrating, and deploying the most feasible SDMS alternative and concept of operations

Note: This document is the Final Report for the contract under which the study was performed. During the course of the study, separate Task Reports for each of the major tasks completed were also delivered, as were several Appendices. These are available under separate cover.

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16. Abstract

This study focused on developing and analyzing various concepts of operation that would link advanced onboard vehicle and driver monitoring technologies with a means of wirelessly communicating such information to local enforcement agencies in order to improve the quality, efficiency, and effectiveness of the North American Standard (NAS) roadside safety inspection program. The hypothesis which prompted the study was that wireless inspection technology could be widely deployed at both traditional and "virtual" inspection sites to dramatically increase the number of "inspections" completed, and to improve pre-screening of vehicles for more detailed manual inspections. Information about the condition of the vehicle and the driver would be assembled electronically in a standard "safety data message set" and then transmitted to the infrastructure, using dedicated short-range communication (DSRC) technology. Concepts developed were differentiated from current electronic pre-screening programs in that real-time information about the vehicle and driver would be conveyed.

Based on a review of inspection and crash data, as well as discussions with the commercial motor vehicle (CMV) industry, the high-level requirements for a wireless commercial vehicle inspection concept should focus on gathering data related to the brakes, tires, lighting systems, Hours-of-Service (HOS), commercial driver's license (CDL) information, carrier identity, and vehicle identification number (VIN). All of this information already exists on the vehicle (via discrete sensor systems or electronic control modules) and, by using conventional technologies, could be electronically linked to the serial databus for subsequent transmission to the infrastructure access points. This information, when combined with the historical information already available on carriers and drivers—accessible via Motor Carrier Management Information System (MCMIS) and/or State CMV databases—would provide the enforcement community with a very powerful decision support tool for screening vehicles and/or implementing virtual, automated, wireless inspection sites.

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Unclassified	**Unclassified**	**84**	

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lbs)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m2	cd/m2
		FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N
psi	pound-force per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	Yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lbs)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi

*** SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.**

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ACRONYMS

ABS	Anti-lock Brake Systems
ATA	American Trucking Association
ATMs	Automated Teller Machines
AVI	Automatic Vehicle Identification
CAN	Controller Area Network
CARB	California Air Resources Board
CDL	Commercial Driver’s License (also referred to as “Driver Identification Information”)
CDLIS	Commercial Driver’s License Information System
CMV	Commercial Motor Vehicle
CSA	Comprehensive Safety Analysis
CVII	Commercial Vehicle Infrastructure Integration
CVISN	Commercial Vehicle Information System and Network
CVO	Commercial Vehicle Operations
CVSA	Commercial Vehicle Safety Alliance
DHS	Department of Homeland Security
DMV	Departments of Motor Vehicles
DSRC	Dedicated Short-range Communication
ECBS	Electronic Controlled Brake Systems
ECM	Electronic Control Module
ECU	Electronic Control Unit
EOBR	Electronic Onboard Recorder
EPA	Environmental Protection Agency
ESS	Enhanced Screening Stations
FARS	Fatality Analysis Reporting System
FCC	Federal Communications Commission
FMCSA	Federal Motor Carrier Safety Administration
FOT	Field Operational Test
GES	General Estimates System
HOS	Hours-of-Service
IEEE	Institute of Electrical and Electronics Engineers
IRIS	Infrared inspection system
ISS	Inspection Selection System
ITS	Intelligent Transportation Systems

JPO	Joint Program Office
LDWS	Lane Departure Warning Systems
LTCCS	Large Truck Crash Causation Study
MCMIS	Motor Carrier Management Information System
NAS	North American Standard
NHTSA	National Highway Transportation Safety Administration
OBD	Onboard Diagnostic
OEM	Original Equipment Manufacturer
O&M	Operation and Maintenance
OOS	Out-Of-Service
PBBT	Performance-based Brake Tester
PDO	Property Damage Only
PRISM	Performance and Registration Information Systems Management
RFI	Request for Information
RFID	Radio Frequency Identification
ROI	Return-On-Investment
SAE	Society of Automotive Engineers
SEA	Safety Evaluation Area
SDMS	Safety Data Message Set
TMC	Truck Maintenance Council
TPMS	Tire-Pressure-Monitoring Systems
TRB	Transportation Research Board
TSA	Transportation Security Administration
TWIC	Transportation Workers Identification Credentials
USDOT	U.S. Department of Transportation
VIN	Vehicle Identification Number
VII	Vehicle Infrastructure Integration
VIS	Virtual Inspection Station
VMT	Vehicle Miles Traveled
WiFi	Wireless Fidelity
WIM	Weigh-In-Motion

EXECUTIVE SUMMARY

PURPOSE

This study focused on developing and analyzing various concepts of operation that would link advanced onboard vehicle and driver monitoring technologies with a means of wirelessly communicating such information to local enforcement agencies in order to improve the quality, efficiency, and effectiveness of the North American Standard (NAS) roadside safety inspection program. The hypothesis which prompted the study was that wireless inspection technology could be widely deployed at both traditional and "virtual" inspection sites to dramatically increase the number of "inspections" completed, and to improve pre-screening of vehicles for more detailed manual inspections. Information about the condition of the vehicle and the driver would be assembled electronically in a standard "safety data message set" (SDMS) and then transmitted to the infrastructure using some type(s) of short-range communication media. Concepts developed were differentiated from current electronic pre-screening programs in that real-time information about the vehicle and driver was conveyed.

The technology deployed would allow for "safe" vehicles to bypass inspection points, while vehicles with defects, or for which proper credentialing could not be verified, would be required to enter the station for more complete (manual) inspections. As the technology matures, it might eventually be used to issue warnings or violations directly to operators in a manner analogous to red-light running cameras. Therefore, this technology could offer a significant deterrent effect and lead to improved vehicle safety and driver operations.

PROCESS

This study represents a comprehensive initial examination of wireless commercial motor vehicle (CMV) inspection concepts. The study process included the following steps:

- Issuance of a public Request For Information (RFI)
- Survey of State enforcement agencies
- Interviews with key stakeholders, including fleet operators and vehicle Original Equipment Manufacturers (OEMs)
- Site visits to State commercial motor vehicle (CMV) inspection facilities
- Attendance at industry meetings [Truck Maintenance Council (TMC), Society of Automotive Engineers (SAE), and Transportation Research Board (TRB)]
- Inspection data analysis [Motor Carrier Management Information System (MCMIS)]
- Comprehensive crash data analysis [Large Truck Crash Causation Study (LTCCS), General Estimates System (GES), Fatality Analysis Reporting System (FARS), MCMIS]

RATIONALE AND BACKGROUND

While it has been successful at identifying a portion of the unsafe vehicles and drivers operating on the roads of the United States, the North American CMV inspection program is challenged by several factors:

- A very large population of CMVs with diverse operations
- Significant growth and fleet turnover in the CMV industry
- Limited resources

In addition, there are other important events taking place in the CMV industry which will shape the manner in which roadside inspections are completed in the future:

- Advances in onboard, automated diagnostic technologies
- Standardization efforts for Electronic Onboard Recorders (EOBRs)
- Developments in the Commercial Driver License (CDL) area
- Standardization efforts for wireless vehicle-to-roadside communications
- Needs of other Federal agencies for monitoring CMVs

Because of these technology, market, and institutional issues, there is a need to do more with less, and wireless, automated inspection technology offers such a means.

STUDY FINDINGS

Key findings from the investigation are as follows:

- If a CMV is not overweight, the probability of its being inspected is exceedingly low. The average CMV is inspected less than once a year—and for fleets with "poor" safety practices, safety inspections are likely not a major deterrent or "threat."
- A large portion of commercial vehicles (e.g., straight trucks and/or "intra-city" combination vehicles) may be subjected to a safety inspection rarely or never. A majority of safety inspection sites are located along the interstate highway system. However, about 50 percent of all CMV crashes are on secondary roads.
- The CMV weight enforcement programs administered by States appear to be highly successful in reducing weight-related violations, most likely because of the very high frequency of weight inspections. This fact suggests that a substantial increase in safety inspection frequency could yield similar benefits for other types of violations.
- Each State would likely mix and match various wireless data collection methods (e.g., fixed facilities, virtual stations, mobile units, etc.) to suit their particular needs.
- A modest wireless, automated inspection infrastructure consisting of 2,000 to 3,000 access points could potentially generate 300 to 500 million CMV electronic inspections each year—compared with a total of 3 million "manual" inspections currently completed by States.
- With the support of the U.S. Department of Transportation (USDOT), 5.9 GHz Dedicated Short-Range Communications (DSRC) will likely become the nation's standard vehicle-

to-roadside communications media for both the heavy- and light-duty vehicle sectors, and will support a variety of market-driven safety and commercial applications. This communications media is therefore an appropriate technology to support the CMV wireless inspection concept.

- Fleets will not voluntarily support wireless inspections unless economic benefits can be demonstrated—and current electronic pre-screening programs already allow trucks to bypass inspection stations. Federal Government-sponsored initiatives (standards, public-private partnerships, regulations, etc.) will be required to spur widespread deployment.
- Based on work completed to date, the high-level requirements for a wireless commercial vehicle inspection concept should focus on gathering data related to the brakes, tires, lighting systems, Hours-of-Service (HOS), CDL information, carrier identity, and Vehicle Identification Number (VIN). All of this information already exists on the vehicle (via discrete sensor systems or electronic control modules) and, by using conventional technologies, it could be electronically linked to the serial databus for subsequent transmission by a wireless communications media. When combined with the historical information already available on carriers and drivers (accessible via Inspection Selection System [ISS], Commercial Driver's License Information System [CDLIS], or other State databases), this information would provide the enforcement community with a very powerful decision support tool for screening vehicles and/or implementing virtual, automated wireless inspection sites.
- The Environmental Protection Agency (EPA) is currently engaged in the development of a heavy-duty emissions inspection program. The technical development work needed to support the EPA effort has many parallels with work that would be required to develop automated safety inspections. Therefore, the opportunity exists for EPA and FMCSA to work cooperatively on a combined wireless safety and emissions inspection program.
- Increased inspection frequency and subsequent enforcement tactics such as violations, fines, etc., would result in a positive shift in carrier safety practices, particularly for those carriers with "poor" safety records.
- While there will be substantial institutional challenges associated with gathering even basic driver and vehicle information wirelessly, the fact that such information is already regularly required by enforcement agencies and routinely given by fleet operators suggests that such challenges can be met.

CONCLUSIONS

Considering FMCSA's role as an enforcement agency, should FMCSA move forward with research in wireless inspection concepts? Is the time right to pursue research in this area, or would technical, institutional and/or cost considerations negatively impact this initiative?

Based on the calculated cost-benefit ratios, interviews with a variety of industry stakeholders, feedback from the public RFI process, and the important changes occurring within the commercial trucking industry, the Research Team concluded that the answer is a clear "yes."

The rationale for pursuing research related to the wireless inspection concept is summarized as follows:

- The concept offers an overwhelmingly positive cost-benefit ratio.
- No new technology is required.
- The concept would support the needs of other Federal agencies as they relate to emission inspections and security-related applications.
- Implementation costs are likely to come down, while available onboard safety information will increase as onboard diagnostics, driven by market forces, continue to improve.
- The wireless inspection concept supports Comprehensive Safety Analysis (CSA) 2010 Goals.
- The current Commercial Vehicle Information System and Network (CVISN) and COMPASS efforts provide an ideal information and communications platform for supporting the wireless inspection concept.

DEPLOYMENT STRATEGIES

Two broad approaches for deploying the wireless inspection concept were identified:

1. Leverage the current Vehicle Infrastructure Integration (VII) effort being sponsored by the Joint Program Office (JPO).
2. Use a regulatory-based approach.

Leverage Current VII Development Efforts

Wireless inspections represent only one of many safety applications that could be enabled through standardized vehicle-to-infrastructure communications using the 5.9 GHz DSRC platform. Just as important, the DSRC medium allows for the development of numerous commercial and convenience applications that offer added value to commercial vehicle fleets, shippers, and vehicle OEMs. Therefore, the deployment of a wireless inspection program could coincide with a larger initiative to encourage the adoption of DSRC technology within the commercial-vehicle heavy-duty sector. From FMCSA’s perspective, wireless safety inspections may represent the primary application that is enabled by DSRC, but there are clearly many other safety and non-safety applications that will help build the business case for adoption of this standardized communications media by the industry.

Once the industry adopts the DSRC technology, costs to introduce the wireless inspection concept would be greatly reduced. At that point, either a direct regulatory approach could be taken that would require downloading of safety data, or a “soft” regulatory approach could be considered whereby FMCSA would leverage its influence with states so that they would modify electronic pre-clearance programs to require additional, real-time safety data to be downloaded before vehicles would be permitted to bypass inspection stations. Leveraging the VII program and DSRC technology to implement a “soft,” voluntary approach to CMV safety inspections is recommended.

Regulatory Approach

A regulatory approach appears feasible, based on its potential safety benefits and as demonstrated by the encouraging Return-On-Investment (ROI) calculations outlined in this Report. The DSRC technology would provide a standardized link to cost-effectively monitor HOS, detect major vehicle condition problems, implement required emission diagnostics to ensure environmental compliance, and determine whether the operator of the vehicle had a current, valid CDL. Security applications that focus on tracking hazardous material shipments, including the ability to report real-time proximity of hazardous shipments to high-risk infrastructure locations (e.g., schools, urban centers, and stadiums) also represent high-payback applications.

Additionally, a phased-in regulatory approach, particularly one that allows exemptions for certain types of fleets, may be supported by some sectors of the industry because it reduces uncertainty and risk for both OEMs and fleets. For vehicle OEMs and equipment suppliers, it creates a level playing field with regard to product offerings. All trucks would have to be equipped with DSRC when the regulations go into effect, thus eliminating an OEM's concerns about whether or not the market would accept the new technology. Additionally, fleets would not need to evaluate the way in which purchasing the new technology would impact their competitiveness, since the new requirement for wireless inspections would simply be a cost of doing business that would be equal for all fleets purchasing new vehicles.

1.0 INTRODUCTION

This study focused on developing and analyzing various concepts of operation that would link advanced onboard vehicle and driver-monitoring technologies with a means of wirelessly communicating such information to local enforcement agencies in order to improve the quality, efficiency, and effectiveness of the North American Standard (NAS) roadside safety inspection program. The hypothesis which prompted the study was that wireless inspection technology could be widely deployed at both traditional and "virtual" inspection sites to dramatically increase the number of "inspections" completed and to improve pre-screening of vehicles for more detailed manual inspections. Information about the condition of the vehicle and the driver would be assembled electronically in a standard SDMS in a manner similar to the way in which diagnostic information on vehicle emission systems (for light-duty vehicles) is used to facilitate standardized emission inspections. Driver, vehicle, and carrier identifier information would also be part of the message set. This information would then be transmitted by an onboard wireless communications control module that would "assemble" the message from various sources on the vehicle (principally the vehicle's electronic network) and then transmit the message to the infrastructure using some type(s) of short-range communication media.

The technology deployed would allow for "good" vehicles to bypass inspection points and could eventually be used to issue warnings or violations directly to operators in a manner analogous to red-light running cameras. Such technology could potentially offer a significant deterrent affect and lead to improved vehicle safety and driver operations. The types of vehicle and operational data that could be monitored and then transmitted wirelessly to an inspection "access point" are shown in Figure 1.

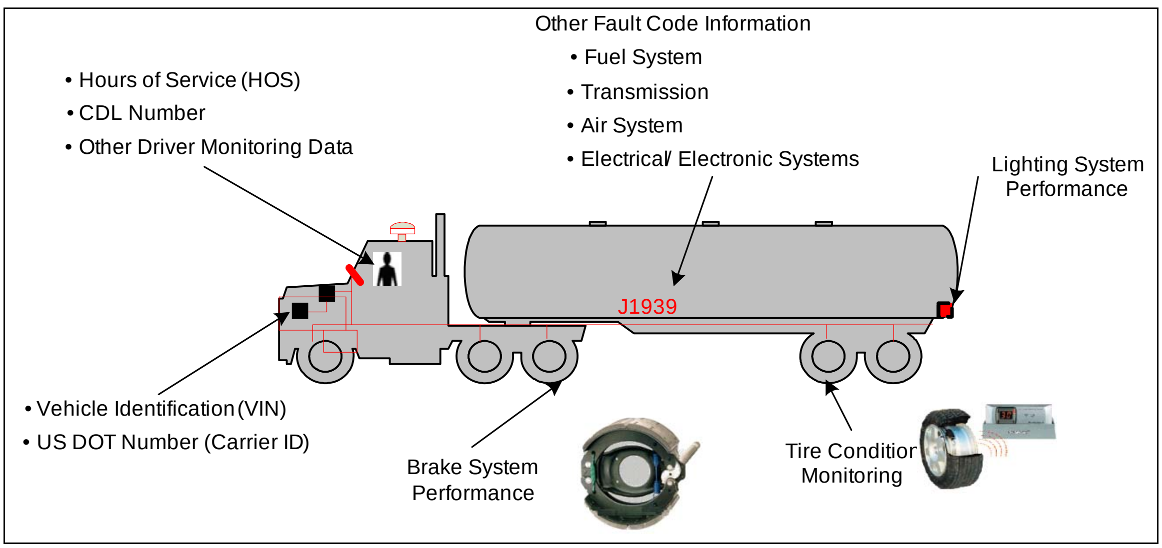

Figure 1. Potential Vehicle and Driver Parameters Included in a "Virtual" Inspection

The concept was significantly differentiated from current electronic pre-screening programs in that real-time information about the condition of the vehicle (e.g., brake, tire diagnostics; etc.) and the driver [e.g., Hours-of-Service (HOS) status] would be transmitted to enforcement agencies. Current pre-screening programs such as NorPass and PrePass only transmit a unique ID number [via the onboard radio frequency identification (RFID) tag] which is then crossreferenced to a U.S. Department of Transportation (USDOT) number in an off-board operation. Further, the proposed concept would call for driver- and vehicle-specific ID information to be transmitted, thus facilitating the implementation of more sophisticated and accurate screening strategies. With current electronic screening programs, vehicles that have significant defects and/or that are being operated by drivers who are in violation of HOS regulations (or who have invalid CDLs) are regularly permitted to bypass inspection sites as long as they are within weight limits and their carrier ID is recognized as a "good carrier." Alternatively, many vehicles that do not have defects and/or are not in violation of HOS regulations are routinely stopped and checked. Under the proposed wireless inspection concept, both of these situations (i.e., false positives and false negatives) would be eliminated, or at least significantly reduced—thus improving both safety and mobility.

1.1 STUDY ORGANIZATION AND TASKS

This study was organized around five key Tasks:

Task 1. Refine the Work Plan: This was a largely administrative Task to refine the detailed analytical approach for conducting the assignment, including resources, industry interviews, and overall work scope issues.

Task 2. Define Requirements: This Task focused on determining the technical and institutional requirements (as well as challenges) for a wireless inspection concept. This work included developing an understanding of the challenges facing the current roadside inspection program, evaluating advanced vehicle diagnostic technologies for detecting safety system defects, assessing wireless communication technology alternatives, and analyzing inspection and crash data to determine what vehicle- and/or driver-related parameters are most closely linked with crash rates (and should therefore be targeted for wireless inspection).

Task 3. Develop Alternative Concepts of Operation: In this Task, alternative concepts for implementing a wireless inspection capability were examined. The concepts were differentiated primarily by the venue and methods through which data would be gathered. Concepts examined included:

1. Enhanced Screening at Existing Fixed Facilities
2. Virtual, Unmanned Inspection Stations
3. Mobile Inspection Units
4. Ubiquitous Inspection Concept
5. Kiosk Self-Inspection Concept
6. Non-Cooperative Inspection Concept

Each of the six concepts was profiled relative to overall concept description, information logic flow and processes, onboard equipment modifications, infrastructure-based equipment requirements, and supporting information system needs.

Note: This last concept (non-cooperative) did not include provisions for the wireless transfer of data by the vehicle, but instead focused on the use of advanced, non-invasive technologies such as infrared detection, optical sensors, and/or size and weight detection technologies.

Task 4. Evaluate and Select an "Optimal" Concept: As initially envisioned, Task 4 was to have focused on evaluating each of the above concepts based on costs, safety benefits, operational considerations, and institutional deployment issues. A "most favored" concept would have been selected and would have become the basis of deployment planning in Task 5. During the assignment, however, the Project Team concluded that no single deployment concept was "optimal" for all operating environments. Rather, an optimal deployment of wireless inspection technology would more likely involve utilization of multiple venue-based concepts (e.g., fixed stations, mobile units, virtual stations, etc.) tailored to the specific needs and operating environments of each state. In other words, it became apparent that the best approach for states would be that of a portfolio whereby states could mix and match the venue-based concepts in the way that would be most cost-effective for their particular operating environments and geographies.

To proceed with Task 4, alternative wireless inspection concepts were redefined based on the specific types of information to be collected rather than on the venue/processes for collecting it. The specific type and amount of data collected will have major impacts on:

- Required onboard equipment and diagnostic systems
- Costs for modifying the vehicle
- Institutional and deployment considerations
- The likely safety benefits to be derived from long-term changes in fleet and driver behavior (resulting from increased inspection of specific parameters)

The concepts were redesigned to represent a range of complexity, costs-to-implement, and potential safety benefits. Again (and by coincidence), six alternative concepts were developed ranging from collection of simple fault code data on selected safety systems (data that is for the most part already available on the vehicle's electronic databus) to collection of more complex diagnostic information on the condition of the vehicle and the driver. These latter concepts would require installation of special-purpose sensors and driver-monitoring systems, and therefore offer more safety-related information, but at a higher cost.

Task 5. Develop a Deployment Plan: Task 5 focused on developing technical and business deployment strategies for the most promising concept identified in Task 4.

Technology research and test plans were outlined, as was a path for widespread deployment in the commercial vehicle sector. Alternative plans involving both a regulatory and a market-based approach were also developed.

1.2 INFORMATION SOURCES

This study represented a comprehensive initial examination of wireless CMV inspection concepts. The study process included:

- **Issuance of a Public Request For Information** (RFI) focused on advanced vehicle diagnostics and wireless inspections. During the study period, responses were received—and a review of the responses is included in the Report.

- **Survey of State Enforcement Agencies** focused on their perspectives on use of advanced diagnostic technologies and wireless pre-screening methods [co-sponsored with the Commercial Vehicle Safety Alliance (CVSA)]. A high-level summary of the survey is provided.
- Interviews with Key Stakeholders:
  - Fleet Operators
  - Vehicle OEMs
  - Technology Suppliers
- Site Visits to State CMV Inspection Facilities (in Maryland and Virginia).
- **Attendance at Industry Meetings** (TMC Annual Meeting, SAE Commercial Vehicle Symposium, and TRB Annual Meeting) to gain additional insight.
- **Reviewed and Analyzed MCMIS Inspection Data** vehicle and driver violations on straight and combination trucks for 2003 and 2004.
- **Reviewed and Analyzed CMV Crash Data Summaries** (LTCCS, FARS, MCMIS) to categorize "critical reason" and "related factors" contributing to CMV accidents.

Each Study Task is reviewed in the following sections.

2.0 DEFINE REQUIREMENTS

2.1 BACKGROUND ON CURRENT ROADSIDE INSPECTION PROGRAM

The NAS Inspection Program was developed to coordinate CMV roadside inspection efforts among States, and to focus on the vehicle and driver safety factors most often associated with CMV crashes. This program is designed to improve safety and promote uniformity in compliance and enforcement, while minimizing duplication of inspection efforts and unnecessary operating delays for the motor carrier industry.

The CMV roadside inspection program represents one of USDOT's most formidable tools for monitoring and regulating the condition of the in-use commercial vehicle fleet, as well as for auditing and enforcing driver- and operations-related safety practices. Driver parameters examined include hours of service logs, CDL status, and other operating credentials, such as permits, proof of insurance, and operating authority. Vehicle parameters examined include weight, cargo securement, and condition of brakes, tires, suspension, lighting, and other safety-related systems.

In 2003, the NAS Inspection program resulted in approximately 3 million CMV roadside inspections, conducted primarily by State enforcement agencies. These 3 million inspections resulted in about 6.75 million violations being issued to motor carriers. Approximately 73 percent of the 3 million vehicles inspected were issued one or more violations—most of them minor infractions. However, about 7 percent of driver violations and 23 percent of vehicle violations resulted in out-of-service (OOS) violations, indicating that the driver or the vehicle was unfit for service. Altogether, these more severe violations (driver plus vehicle) resulted in placing about one out of every four vehicles inspected out of service. This data is shown in Table 1 and Table 2.

The process of targeting vehicles for inspection has been aided in the past few years by the implementation of the Inspection Selection System (ISS). This system uses information on past inspections and carrier safety ratings to assist the inspection officer in making a decision on whether or not to inspect a particular vehicle. This system is not yet operational nationwide, and only a few States utilize the full capability of ISS.

Table 1. Roadside Inspection Violation Data (All Trucks)—Summary

All Inspections	Number	Percent
Number of Inspections	3,006,919	
With no Violations	811,335	26.98%
With Violations	2,195,584	73.02%

Table 2. Roadside Inspection Violation Data (All Trucks)—Detail

	Total Inspections	Driver Inspections	Driver OOS	Driver %	Vehicle Inspections	Vehicle OOS	Vehicle %
Level 1	1,007,933	1,007,933	52,887	5.25%	1,007,933	294,554	29.22%
Level 2	1,097,392	1,097,392	73,995	6.74%	1,097,392	193,995	17.68%
Level 3	822,635	822,635	71,883	8.74%	0	0	0
Level 4	22,268	0	0	0	0	0	0
Level 5	16,208	0	0	0	16,208	2,314	0
All	2,955,436	2,927,960	198,765	6.79%	2,121,533	490,863	23.14%

2.2 NEED FOR CHANGE

While it is successful at identifying a portion of the unsafe vehicles and drivers in operation, the North American CMV inspection program faces several challenges:

- A very large population of CMVs with diverse operations
- Significant growth and fleet turnover in the CMV industry
- Limited resources

2.2.1 Profile of CMV Population and Operations

According to the most recent Vehicle Inventory and Use Survey, there are about 5.5 million commercial vehicles operating above 10,000 pounds GVW in the United States. Table 3 shows a breakdown of the CMV population by vehicle type and range of operation. As shown in the figure, almost two-thirds of all CMVs are straight trucks and, as can be seen by segmenting the population based on range of operation, most trucks (65 percent) operate within 50 miles of their "home base."

Table 3. Truck Population by Type[1]

TRUCK TYPE	Medium Weight Class: WEIGHT	Medium Weight Class: %	Light-Heavy Weight Class: WEIGHT	Light-Heavy Weight Class: %	Heavy Weight Class: WEIGHT	Heavy Weight Class: %	Total: WEIGHT	Total: %
Total	1,914	100%	911	100%	2,590	100%	5,415	100%
Straight Truck	1,512	79%	821	90%	1,102	43%	3,435	63%
Combination Truck	402	21%	90	10%	1,488	57%	1,980	37%

[1] United Status Census Bureau, Vehicle Inventory and Use Survey 2002, U.S. Department of Commerce, Washington, DC: 2004.

Table 4. Truck Population by Range of Operation[2]

RANGE OF OPERATION	Medium Weight Class WEIGHT	Medium Weight Class %	Light-Heavy Weight Class WEIGHT	Light-Heavy Weight Class %	Heavy Weight Class WEIGHT	Heavy Weight Class %	Total WEIGHT	Total %
Total	1,915	100%	910	100%	2,590	100%	5,415	100%
50 miles of Less	1,365	71%	702	77%	1,451	56%	3,514	65%
51 Miles or More	550	29%	208	23%	1,139	44%	1,902	35%

Since most inspection stations are located on major Federal interstate highways, these statistics suggest that a large percentage of commercial vehicles (straight trucks and/or larger "intra-city" combination vehicles) will rarely or never be subjected to safety inspections by commercial vehicle enforcement agencies. To some extent, the focus on combination vehicles and long-haul trucks is appropriate, as the majority of crashes and fatalities in the commercial vehicle sector involve combination vehicles. However, it should be noted that about 27 percent of all CMV fatalities involve straight trucks, and about 50 percent of all CMV crashes are on secondary roads. Many States are successfully using mobile/portable inspection sites to better target intra-city trucks and/or trucks that use non-interstate roads. The use of mobile inspections is growing, and it is estimated that 800,000 to 1,200,000 of the 3 million roadside inspections are completed using portable or mobile equipment.

2.2.2 Industry Growth

The NAS roadside inspection program is also challenged by significant growth in the heavy-duty vehicle segment, as shown in Figure 2. For example:

- Combination vehicle population and vehicle miles traveled (VMT) are growing at about 3.3 percent per year.
- The population of straight trucks is also growing at about 3 percent per year, while VMT is growing at a slightly lower rate, about 2 percent annually.
- There are about 40,000 new entrants into the commercial vehicle operations (CVO) market each year, and about half of those drop out.
- Over the last 20 years, there have been one million new combination vehicles added to our nation's highway network.

2.2.3 Limited Resources

The number of roadside inspection facilities has remained relatively static over the past several years, with a total of approximately 1,200 facilities in the United States staffed by about 10,000 employees. Very few States have invested in fixed-facility inspection stations and some States have even reduced their fixed-station activities while slightly increasing their mobile/portable

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[2]United Status Census Bureau, Vehicle Inventory and Use Survey 2002, U.S. Department of Commerce, Washington, DC: 2004.

inspection programs. While detailed historical investment data is lacking on a State-by-State basis, the consensus among those interviewed (which included CVSA staff and State CMV enforcement agencies) is that increases in labor and facilities (fixed and mobile combined) for roadside inspections has, at best, remained flat, with some notable exceptions, such as Texas and California, which have invested heavily in their roadside inspection programs.

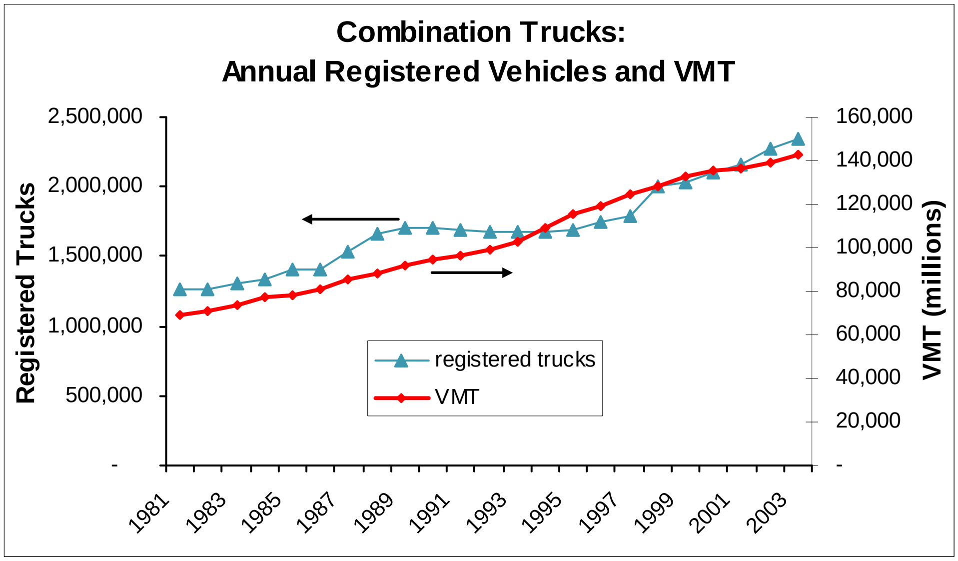


Figure 2. Growth in the Commercial Vehicle Sector

The increase in the overall CMV population has put a strain on the roadside inspection program. States appear to be responding by increasing the relative percentage of Level 2 (driver-plus-walk-around) or Level 3 (driver-only) inspections as a substitute for full Level 1 inspections, in order to keep up with the increasing vehicle population. This trend is shown in Figure 3.

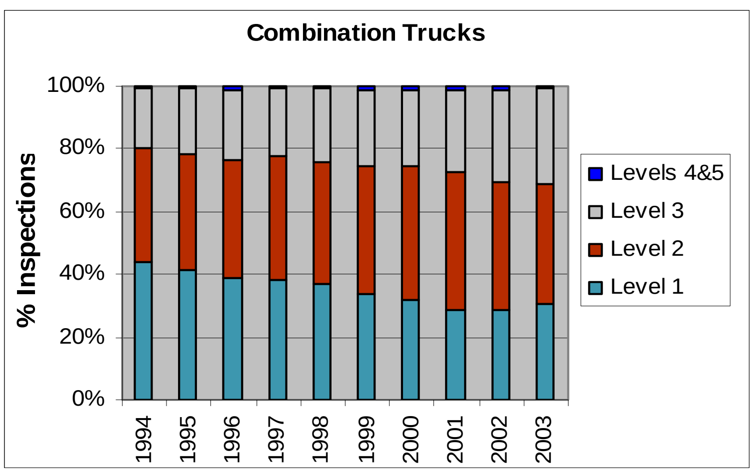


Figure 3. CMV Inspections by Level Type (1994 to 2003)

In 1994, Level 1 inspections represented about 45 percent of all inspections, while in 2003 this number had dropped to about 30 percent. Also, as noted, it appeared that States were increasing their mobile inspection efforts, with approximately one-third of all inspections completed by mobile units.

Overall, however, the current level of roadside inspection activities results in relatively infrequent inspections for the average truck. This data is shown in Table 5.

Table 5. Average Miles between Inspections (CY 2003)

	VMT (million miles)	VMT %	Registered Commercial Vehicles	RCV %	Total # of Inspections Completed	TIC %	Avg Annual Miles per Vehicle	Avg Miles Between Inspections
Combination Vehicles	142,802	65%	2,344,961	29%	2,181,433	74%	60,898	65,463
Straight Trucks	78,164	35%	5,820,138	71%	785,003	26%	13,430	99,571
Total	220,966	100%	8,165,098	100%	2,966,436	100%	27,062	74,489

The data in Table 5 suggests that, based on a comparison of annual miles per vehicle and miles between inspections, the average combination vehicle will be inspected about once every 13 months, while the average straight truck will be inspected about once every 7.4 years. It should be recognized, however, that the statistical averages reported here (particularly for straight trucks) can be misleading, because of the bias built into State inspection programs. Specifically, States use various databases and tools to target high-risk carriers for inspection, most notably ISS. Therefore, a large percentage of combination vehicles may operate for two or three years without being inspected, while trucks in high-risk fleets may be inspected several times a year. The principal point (confirmed through discussions with fleets and operators) is that vehicle and driver roadside safety inspections occur very infrequently on any given truck. As long as a vehicle is not overweight, the probability of its being selected for a roadside safety inspection is very low. For those fleets with lax safety practices (e.g., those that defer proper maintenance and/or place only weak emphasis on adherence to HOS and other operating regulations), the roadside inspection program does not appear to be a major factor influencing their behavior.

2.3 OTHER FACTORS DRIVING CHANGE IN ROADSIDE INSPECTIONS

In addition to the aforementioned challenges, there are also other important events taking place within the CMV industry that will shape the manner in which roadside inspections are completed in the future:

- Advances in onboard, automated diagnostic technologies
- Standardization efforts for Electronic Onboard Recorders (EOBRs)
- Developments in commercial driver licensing
- Standardization efforts for wireless vehicle-to-roadside communications
- Needs of other Federal agencies for monitoring CMVs

2.3.1 Advances in Onboard, Automated Diagnostic Technologies

It is well-recognized that heavy-duty vehicle electronics continue to advance at a rapid pace. These advances are driven by multiple factors, including competitive pressure to reduce costs, increase functionality and features, and conduct more efficient preventative maintenance. A side benefit of such advances is that they also allow for the early and automatic detection of defects or problems in many subsystems, thus potentially improving vehicle safety. Currently, the output of such systems (i.e., fault codes and system performance parameters) is stored in various electronic control modules as "message sets." This information can then be retrieved by technicians using diagnostic tools that connect to the vehicle's high-speed controller area network (CAN) databus. Newer heavy-duty vehicles utilize a network conforming to SAE standard J1939, while older trucks utilize a slower network called J1708. The output from these diagnostic sensors/systems is also used to provide real-time notification to the driver through dashboard warning lights and/or information displays. Recently, some truck OEMs have offered optional wireless connection capability with the vehicle's CAN databus so that diagnostics can be completed without a physical hardwire connection.

It is certainly feasible that safety-specific diagnostic data (i.e., an SDMS) could be wirelessly transmitted from the vehicle to staffed or non-staffed (virtual) inspection stations at highway speeds. The information could then be used to determine whether more detailed inspections should be completed, and/or to automatically issue warnings or violations to the operator. This concept was recently demonstrated by Volvo and the University of Tennessee in a "Trusted Truck" project partially funded by FMCSA.

Specific safety-related systems in which electronics are increasing the ability to detect defects include:

Brakes: "Standard" anti-lock brake systems (ABS) already have the ability to report failures of multiple components that could compromise braking performance, including faulty wheel speed sensors, actuators, relay valves, and other switches and solenoids in the brake system. FMCSA has recently taken advantage of such ABS system capabilities by requiring that a warning light be added inside the cab of a tractor if the ABS system on a trailer detects a fault. In the future, as ABS systems continue to become more complex, and/or when Electronic Controlled Brake Systems (ECBS) become more commonplace, the ability to automatically detect brake system performance abnormalities will increase. While there are already relatively simple brake stroke sensors available as an option that can send a signal if the stroke is too far out of adjustment, it is likely, as advances in electronics continue, that even more sophisticated brake system diagnostics will become available and will be standard on future CMVs.

Tires: Commercial vehicle tire-pressure-monitoring systems (TPMS) are readily available from multiple vendors. The output of these systems often includes individual tire pressures, and many provide for temperature compensation to yield accurate readings at highway speeds. The digital output signals from such systems could readily be made part of a standard SDMS. TPMS are not yet widely deployed in the marketplace, mainly because of cost and reliability concerns. (A typical TPMS for a tractor-trailer combination costs in the $800–$1200 range, and many require batteries which must be changed periodically.) For the most part, these systems are add-on sensors that mount on the valve stems or wheel hub, or are attached to the inside of the tire. However, the industry appears poised for the introduction of commercial vehicle tires with pressure monitoring chips that are molded into the tires themselves and operate without the use of an internal power source (or battery). Such tire technology would lower costs, increase reliability, and essentially eliminate the need for maintenance of the systems themselves—maintenance requirements which have been a detriment to TPMS in the marketplace.

Other Vehicle Systems: There is a trend in the automotive industry toward use of more by-wire systems in which mechanical actuators and controls are replaced by electronic systems using controllers, solenoids, electric motors, and various transducers (sensors). As noted, ECBS systems are emerging; they are already commonplace in Europe. Electronics are also being added to suspension, steering, fuel, and air supply systems on commercial trucks. Conditions which could compromise vehicle safety, such as low air pressure or leaks, fuel system leaks, suspension system failure, and various types of electrical and lighting system shorts and open circuits, can now be reported automatically in many instances. Such diagnostic information (and fault codes) could be standardized and built into an SDMS. Again, this is a technical approach very similar to what is now commonplace in the light-duty sector for reporting failures or defects in emission-related components. The standardized emission data message set and associated processes for extracting the data are known as "Onboard Diagnostics II," or OBD II. The II designation represents an enhanced version from the original OBD regulations for light-duty vehicles that were introduced in California in the mid-1990s.

Vehicle Weight: There are several methods for a commercial truck to estimate its gross weight. Engine and transmission Electronic Control Modules (ECMs) can use internal algorithms to estimate gross weight by monitoring the torque/speed curves during accelerations and comparing them with "standard" curves based on a reference weight. However, such an approach has limited accuracy, with estimates that may be off by as much as 10 percent (varying wind, road, and other conditions preclude higher accuracy levels). For vehicles that are equipped with an air bag suspension system (both tractors and trailers), weight can be estimated by monitoring air bag pressure and vehicle ride height at each axle. However, these systems add about $1,500 to $2,000 to the cost of a combination vehicle and can be applied only to vehicles with an air suspension system. Alternatively, load cells can be mounted directly to the axles and/or the fifth wheel to directly measure vehicle weights. These systems are more expensive, ranging from $2,500 to $4,000 per vehicle. All of these systems involve certain compromises relative to accuracy, cost, and/or adaptability to all vehicle types. While self-weighing technologies are available from multiple vendors, and are currently offered as an option on many new vehicles, this report indicates that accuracy and cost limitations will prevent them from becoming widespread in the marketplace. Therefore, wireless virtual inspection sites will need to rely on weigh-in-motion (WIM) equipment to determine vehicle weight and to augment the vehicle's SDMS. If and when self-weighing technology does become cost-effective, the digital weight information could readily be added to an SDMS and thus allow for even more flexible roadside inspection concepts.

2.3.2 Electronic Onboard Recorders

FMCSA is currently engaged in rulemaking related to electronic onboard recorders (EOBRs). A probable key element of such rulemaking will be the development of a standardized protocol (or format) for reporting HOS logbook data. It is envisioned that the standardized logbook data will be extracted or downloaded using either a wired connection or a wireless medium such as Bluetooth or WiFi ("wireless fidelity"). This standardization effort in which FMCSA is engaged is an important first step toward enabling the electronic HOS data to be extracted at highway speeds using other wireless media (wireless communication options are discussed in the next section of this study). Essentially, the output data file from an EOBR conforming to FMCSA format specifications could be readily transferred to the vehicle's wireless communications module, where it would become a part of the larger SDMS. Alternatively, electronic HOS recording functionality could be integrated directly into the wireless communications module itself. Such integration could lower costs and provide the path for the marketplace to follow if technology to support wireless inspections were to become standard on commercial vehicles.

2.3.3 Commercial Driver's License Developments

For a wireless commercial vehicle inspection concept to be optimally successful, the SDMS should contain fundamental identification information about the driver, the vehicle, and the carrier. The VIN is already electronically coded and available on the J1939 databus network, and is usually provided by an engine or dash vehicle controller. As such, the VIN could readily be made part of the SDMS. The carrier's USDOT number could be programmed into the onboard radio/recorder unit (i.e., a wireless communications control module that would be central to the proposed wireless inspection concept) using a compatible diagnostic tool in much the same way that such tools are currently used to reprogram electronic control units (ECUs) and clear fault codes. If or when the vehicle changes ownership, the carrier's USDOT number could be reprogrammed by the new operator using available diagnostic tools. The management of electronic USDOT numbers for specific vehicles and fleets relative to updates, changes in status, and ownership would be handled in much the same way that current USDOT number decals are handled. An alternative concept would be to transmit only the VIN number (which is permanently linked to a particular vehicle) and match the VIN to a particular carrier or USDOT number using a reference database. While development and operation of such a database are challenging and would require close cooperation with States, such an effort is already being implemented under the Performance and Registration Information Systems Management (PRISM) effort.

The inclusion of a driver's license number as part of the SDMS is more challenging, inasmuch as it would require operators to digitally identify themselves to the truck's electronic CAN. Technical solutions are available, such as the use of a standardized CDL "smart license" that contains a digitally coded CDL number, expiration date, restrictions, and other information. Such a card could be inserted into the vehicle's dash as part of the ignition and starting procedure. Various technologies already exist and are used by some fleets as a way to manage/audit driver work hours/miles. Each technology—for example, "contact" and "contactless" cards—has its performance and cost trade-offs. The cost of the smart card itself would be very low (less than $10). A very rough cost estimate for modifying a vehicle to include a card reader, along with an interface to the vehicle's electronic network, is $50 to $100.

If positive driver verification is required, then biometric information could also be included on the card, and provisions for reading the same biometric identifier would be built into the truck to verify a match. Such concepts are readily available and have been demonstrated by FMCSA as part of the recent Hazardous Materials Field Operational Test (FOT). However, such concepts would also increase cost and complexity.

There are two important programs which may impact the evolution of CDLs and their use for electronically identifying the driver to the truck: Transportation Workers Identification Credentials (TWIC) and REAL ID.

TWIC: The Transportation Security Administration (TSA) is mandated by Federal legislation to develop an ID system for individuals who need access to secure areas of the nation's transportation system. The TWIC program will allow implementation of a nationwide standard for secure identification of transportation workers and access control for transportation facilities. Current estimates are that 12 to 15 million workers will be required to carry TWIC cards. The TWIC card is still in the very early stages of development, with the first pilot programs focused on port and maritime activities. Technically, the TWIC card is envisioned as a flexible, programmable smart card that could readily be used as a secure way for drivers to identify themselves to their trucks. Whether and how the TWIC program could be leveraged to support the wireless inspection concept requires additional investigation. It is clear, however, that a TWIC card could technically provide a standardized and controlled mechanism for digitally identifying the driver to the truck, and thus facilitate the inclusion of such data in an SDMS.

REAL ID: In addition to TWIC, Federal legislation was passed in May of 2005 for the U. S. Department of Homeland Security (DHS), along with individual State Departments of Motor Vehicles (DMVs), to begin working together to develop what would be a national ID card. In practical terms, the Federal Government will establish technical and physical standards for the ID card to which States must adhere. Most likely, the REAL ID card, depicted in Figure 4, will take the form of a driver's license. The focus of the REAL ID program is to increase security and authenticity standards for the issuance of State IDs or driver's licenses. Information contained on the card will include, at a minimum, name, birth date, sex, ID number, a digital photograph, address, and a common machine-readable technology. This could be a magnetic strip, enhanced bar code, or RFID chip. The card must also support "physical security features designed to prevent tampering, counterfeiting, or duplication of the document for fraudulent purposes." DHS is permitted to add additional requirements, such as a fingerprint or retinal scan, on top of these minimal information requirements. Like the TWIC card, the REAL ID card could become an important tool for positively (and electronically) identifying the driver to the truck.

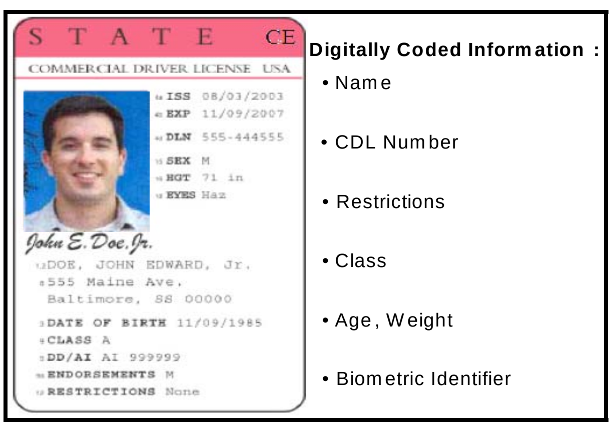


Figure 4. Rendition of the REAL ID card.

As noted, the inclusion of an operator's CDL number as part of the SDMS would permit enforcement personnel (either at a stationary inspection facility, or in a mobile patrol vehicle) to download the information, check it against CDLIS and other databases for any issues/problems, and then decide whether the vehicle/driver should be targeted for more detailed inspections. While the benefits of having the CDL information as part of the downloaded data set would appear significant, it is not necessarily critical to the wireless inspection concept. Real-time information on vehicle diagnostics, driver HOS logs, the VIN number, and USDOT number would also provide important and useful data.

2.3.4 Wireless Vehicle-to-Roadside Communications

There are numerous wireless technologies currently available or under development that could support wireless inspections. These technologies vary significantly in range, bandwidth, security, current deployment level, complexity, and cost. Due to the many technical challenges associated with the wireless inspection concept (i.e., speed of the traveling vehicles, message size requirements, security provisions, and implementation costs), the most promising short-range communications technologies appear to be 5.9 GHz DSRC, WiFi, or 900 MHz DSRC.

***WiFi (or Conventional 802.11a/b)**:* For wireless inspection stations located at fixed facilities or at "virtual" locations, WiFi technology (802.11a operates in the 5 GHz band, while 802.11b operates at 2.4 GHz) could work, but with significant operational compromises. Significant application engineering and development work would be required, as WiFi is not intended to be used by a moving vehicle. The range on an 802.11b access point is only 300 feet, which means that a vehicle traveling 60 mph would only be in range for 3.4 seconds, not enough time to connect with the access point and download the SDMS securely. A significant development effort involving multiple roadside antennae, high-speed message transfers, and merging of data would be needed. Using WiFi, a vehicle would probably have to slow down and be directed to a dedicated, single-file lane to perform the transfer. Overall, WiFi technology would be a viable interim technology for testing and demonstration, but would not be viable to support efficient, cost-effective data transfer.

Conventional Toll Tag Technology: Nine hundred (900) MHz DSRC communications are widely used in Europe and U.S. toll collection and transponder systems. This is also a viable short-range technology, and commercial systems are currently available. The technology has been proven in the moving vehicle environment and the radios are relatively affordable. However, because the range of existing 900 MHz DSRC is typically less than 30 meters, dedicated lanes or multiple access points (one for each lane) similar to current toll tag lanes would be required. In addition, the data rate available with 900 MHz systems is limited. The rate is approximately 0.5 Mbps (compared with 27 Mbps for 5.9 GHz DSRC). This limited bandwidth could significantly impact the size and complexity of the SDMS and could result in reduced inspection data, possible need for onboard compression, slower vehicle speed to transmit more data, or multiple access points.

Dedicated Short-Range Communication (DSRC) at 5.9 GHz (802.11p): While still in development, 802.11p is a new Institute of Electrical and Electronics Engineers (IEEE) standard that is uniquely focused on facilitating vehicle-to-infrastructure and vehicle-to-vehicle communications. The proposed standards (IEEE P1609 series of documents) outline functional and performance requirements, as well as protocols for communicating in a 75 MHz bandwidth range between 5.850 GHz and 5.925 GHz. With support from USDOT, the Federal Communications Commission (FCC) made this spectrum available solely for vehicle use in 2004. DSRC is ideally suited for the wireless inspections, since multiple vehicles could simultaneously communicate with a roadside access point within a one-half-mile range while traveling at high speeds. Most important, 5.9 GHz DSRC is being targeted as the technology of choice to support many other safety and convenience applications currently under development. With USDOT's support, 5.9 GHz DSRC will likely become the standard for vehicle-to-roadside and vehicle-to-vehicle communications in both heavy- and light-duty vehicles. It will support a variety of safety applications, including intersection collision avoidance, road condition warning, curve speed assistance, cooperative cruise control, and many others. So-called convenience applications, such as electronic funds transfer, advanced parking notification, rest stop information, or mobile media will also use the high-data rates of 5.9 GHz communications. Therefore, there will be opportunities to leverage the DSRC infrastructure and onboard vehicle transceivers well beyond just wireless electronic inspections. The aforementioned analysis indicates that DSRC technology is sufficiently robust, offers good security, supports two-way communications, and as a result is well- suited to supporting commercial vehicle wireless inspections.

2.3.5 Needs of Other Federal Agencies for Monitoring CMVs

The technology and infrastructure for electronically interrogating CMVs could be leveraged by other Federal agencies, including the Environmental Protection Agency (EPA) and the Transportation Security Administration (TSA), for emerging environmental and security needs.

EPA: For 2008, the U.S. EPA has mandated a significant reduction in exhaust emissions from heavy-duty vehicles. At the same time, EPA is developing a complete technical and programmatic plan for checking/auditing the in-use compliance of trucks with these new standards. This plan calls for automated onboard diagnostics to report on the performance and/or failure of all emission system components. The heavy-duty program is modeled after the light-duty OBD II program. It requires the vehicle to be capable of assembling and storing a standard "emissions data message set" that reports the performance of emission components under pre-determined conditions. The emission compliance check would most likely be made by connecting a standardized diagnostic tool to the vehicle's controller area network (the J1939 databus) and downloading the data. In other words, just as light-duty vehicles are required to complete emission system checks periodically, heavy-duty vehicles will be required to do the same in the future.

Discussions with EPA and the California Air Resources Board (CARB) indicate that the logistics for how, where, and when emission inspections would take place have not yet been detailed. (California has given some indication that CMV emission inspections might be completed at the roadside by an appropriately trained officer.) Initial discussions with EPA about FMCSA's interest in wireless safety inspections were enthusiastically received. If such a wireless interrogation infrastructure were put into place, it might be leveraged to collect diagnostic data on both emission and safety-related components. Further, EPA is already pursuing the basic technical work to standardize an emissions-related message set. Rather than pursue a different messaging framework and protocol for storing and downloading safety data, FMCSA could choose to leverage the basic technical protocols being put into place by EPA for emission system monitoring. Overall, there appears to be substantial common ground for EPA and FMCSA to work together on a broad wireless inspection project, and early discussions indicate that EPA would like to pursue this idea with FMCSA.

TSA: New strategies and programs are currently being considered for tracking hazardous materials shipments. TSA has recently awarded a contract to General Dynamics to establish a nationwide hazardous materials tracking center. The focus of this work is on leveraging communications between both cellular and satellite telematic service providers and their fleet customers to monitor movement of goods. While satellite/cellular communications may be a reasonable solution for hazardous materials carriers (the large majority of such carriers already utilize these telematic services), it is likely not a viable solution if there were a requirement for monitoring a much larger portion of the CMV freight industry. Standardized, short-range, wireless communication which does not require a service fee for operators does, however, offer a solution that might allow for more widespread tracking and monitoring options.

Wireless information exchange applications that would support the efficient movement of goods across the Canadian and Mexican borders, while also increasing security levels, are also being considered by U.S. Customs. For example, a pilot program is being developed that would call for an electronic freight manifest to be forwarded by carriers about 45 minutes prior to their arrival at the border. The manifest would include information such as bill-of-lading, driver’s license number, VIN, carrier number, and other trip data. This data would be checked against various databases to determine if the vehicle, driver, and/or contents were authorized for entry. The ability to transfer such data wirelessly could enhance the effectiveness of the concept by allowing for all data to be contained within the vehicle and for the easy off-loading of the data along the roadside. Messages/instructions back to the vehicle operator would also be facilitated.

As the wireless safety inspection concept moves forward, it will be important to determine if and how the needs of other Federal agencies involved in freight transport will be included in the overall program. Specifically, additional discussions with EPA, DHS, U.S. Customs, and possibly other agencies, are needed to determine how the wireless inspection concept might be broadened to include the information exchange needs those agencies have in regard to commercial vehicle operators. An FMCSA deployment plan focused only on safety might not be optimal for the trucking community because of the cross-cutting capabilities afforded by standardized wireless-to-roadside vehicle communication.

2.4 WHAT VEHICLE AND DRIVER DATA SHOULD BE TARGETED FOR WIRELESS INSPECTION?

To achieve maximum effectiveness, a wireless inspection program should target the vehicle and driver parameters that are most closely linked to crash causation. It should target those factors that led, either directly or indirectly, to a crash based on historical analysis of the data. An examination of historical inspection and crash data identified such causal factors.

2.4.1 Inspection Data Analysis

Inspection data from 1994 through 2004 were examined, and a detailed analysis of the inspection data was presented in the Task 2 Report. In general, the violation rates in various categories changed very little over the time period, with out-of-service rates caused by driver violations running between 5 and 10 percent, while vehicle out-of-service violation rates remained around 25 percent, as shown in Figure 5.

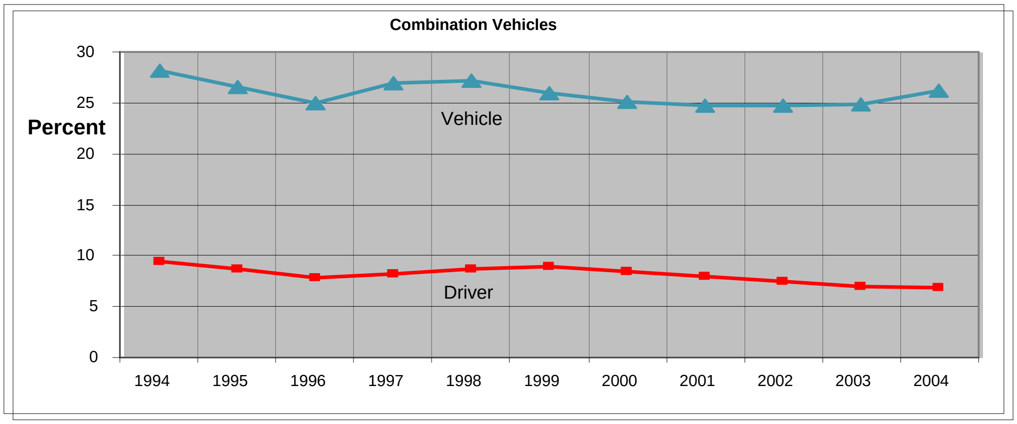


Figure 5. Out-of-Service Violation Rates: 1994 to 2004

To obtain a better understanding of inspection violations, data from 2004 was analyzed in more detail. A high-level summary of the analysis (Table 6) shows that a relatively small number of major violation categories accounted for a large majority of all out-of-service violations. For example, defects associated with brakes accounted for 41 percent of all vehicle OOS violations (which, as noted earlier, account for about 73 percent of all OOS violations). Defective lighting systems (failed brake lights, turn signals, marker lamps, etc.) and poor tire conditions (no tread, low pressure, etc.) were also major OOS violation categories. Improper load securement was also often cited.

Table 6: Leading Vehicle and Driver Out-of-Service Violation Categories

OOS Group	Category	% of OOS Group	Monitorable using currently available sensor systems and electronic data recording technology?
Vehicle	Brakes	41.2%	Yes
	Lighting	16.6%	Yes
	Tires	9.4%	Yes
	Load Securement	15.7%	No
	Total	82.8%	
Driver	All Logbook-Related	67.1%	Yes
	Disqualified Drivers	4.7%	Yes
	All Other Driver Violations[1]	23.4%	No
	Total	95.2%	

(1) "All Other Driver Violations" includes CDL-related violations, registration issues, proof of insurance, and other documentation/permit issues.

For driver-related or non-vehicle-related violations (which account for 27 percent of all OOS violations), problems associated with the logbook were the largest violation category (67 percent), while disqualified drivers (e.g., no license, improper class of license, expired license, etc.) accounted for about 5 percent of driver OOS violations. Problems associated with registration, permits, insurance, and other documentation accounted for about 23 percent of all non-vehicle OOS violations.

Additional analyses were conducted comparing the violation rates between all inspections completed in 2004. An analysis was also conducted on a subset of these inspections that were completed on CMVs which were involved in actual crashes (16,500 such inspections out of a total of 3 million). The post-accident inspection data was screened to eliminate any violations that may have occurred as a result of the accident itself (such as broken lights, load securement problems, etc.). Key findings from this analysis show that:

- HOS-related violations were about twice as high for vehicles in crashes as for all vehicles inspected
- Disqualified driver violations were almost three times as high for vehicles in crashes as for all vehicles inspected
- Instances of brake-related problems were about 2.5–3 times as high for vehicles in crashes as for all vehicles completing inspections
- Load securement violations were about twice as prevalent on vehicles involved in crashes as on all vehicles inspected

2.4.2 Crash Data Analysis

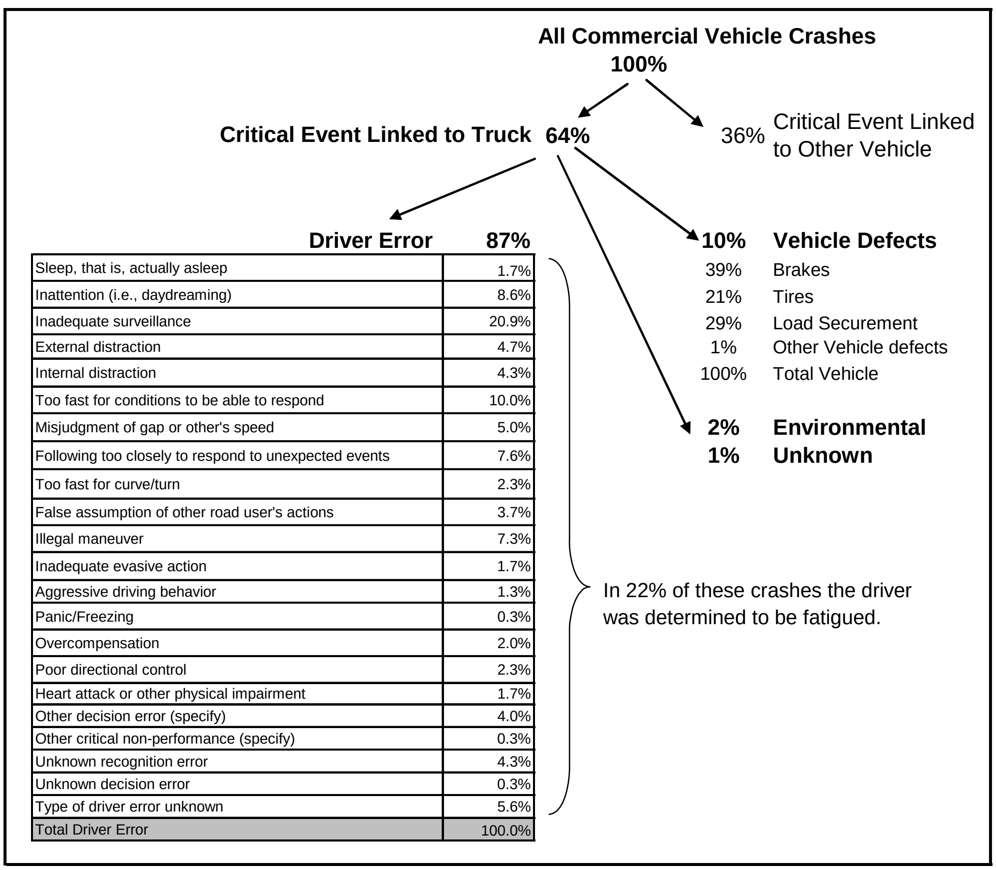
An analysis of crash data which focused on identifying the cause of CMV crashes was also completed; details are presented in Appendix D. This analysis included a review of historic databases [MCMIS, General Estimates System (GES), FARS] and of the newly released Large Truck Crash Causation Study (LTCCS). To a great extent, this analysis confirmed many aspects of conventional thinking regarding the causes of large-truck crashes. For example, a large portion of all commercial vehicle crashes are linked to (or initiated by) the other (non-truck) vehicle involved in the crash. Fatigue was a major contributing factor in those crashes where the commercial vehicle was linked with the critical event leading to the crash. In general, the LTCCS Study provides the most complete, detailed, and recent information about critical events and supporting factors leading to commercial vehicle crashes.

The LTCCS was a 3-year data collection project conducted by the National Highway Transportation Safety Administration (NHTSA) and FMCSA. FMCSA commissioned this study to collect an extensive and nationally representative database on the primary and secondary causes of serious large-truck crashes. Post-crash analyses on vehicles were conducted, as well as interviews with drivers, other occupants, and pedestrians who were involved in the accidents, to reconstruct a complete picture of the accident’s causes and effects. The database includes 57 related tables containing information on 1,070 total crashes, each involving at least one large truck. Sample weights were calculated and applied for each case so that valid national estimates and sample error estimates could be made.

Figure 6 provides an overview analysis of crash data based on the "critical event" code assigned to each crash. This particular table ("critical event") is a key table within the database that assigns the critical event leading to the crash to either the truck or the other vehicle—and then further assigns the critical event to one of several driver, vehicle, or environmental factors.

Key findings from Figure 6 include the following:

- About 60–65 percent of CMV crashes are linked to the truck entity. (This statistic may surprise many industry observers. A somewhat common misperception is that most CMV crashes are caused by the driver of the other vehicle, which most often is a passenger car. The data from the LTCCS shows that for those crashes that involve two vehicles, one a car and the other a truck, more often than not the critical event leading to the crash is assigned to the car. However, there are many CMV crashes that do not involve cars or light-duty vehicles. When <u>all</u> CMV crashes are considered, in most instances the critical event is in fact assigned to the truck.)
- Most of these crashes (87 percent) are linked to driver error.
- While "fatigue" is not directly cited as the "critical reason" for a crash, drivers were cited as being fatigued in 22 percent of CMV crashes where the truck was linked with the critical reason for crash.
- Where a vehicle defect was the critical reason for the crash, brakes, tires, and load securement issues were the factors most often cited.



Driver Error	87%
Sleep, that is, actually asleep	1.7%
Inattention (i.e., daydreaming)	8.6%
Inadequate surveillance	20.9%
External distraction	4.7%
Internal distraction	4.3%
Too fast for conditions to be able to respond	10.0%
Misjudgment of gap or other's speed	5.0%
Following too closely to respond to unexpected events	7.6%
Too fast for curve/turn	2.3%
False assumption of other road user's actions	3.7%
Illegal maneuver	7.3%
Inadequate evasive action	1.7%
Aggressive driving behavior	1.3%
Panic/Freezing	0.3%
Overcompensation	2.0%
Poor directional control	2.3%
Heart attack or other physical impairment	1.7%
Other decision error (specify)	4.0%
Other critical non-performance (specify)	0.3%
Unknown recognition error	4.3%
Unknown decision error	0.3%
Type of driver error unknown	5.6%
Total Driver Error	100.0%

Figure 6. Overview: Analyses of LTCCS Data

2.4.3 Summary of Inspection and Crash Data Analyses

Several key observations emerge from the analyses relative to the design of a wireless inspections concept:

- Driver error far outweighs vehicle-related defects as a factor contributing to commercial vehicle crashes, and fatigue is among the dominant factors contributing to driver error. Therefore, technologies and methods for directly or indirectly monitoring driver performance and fatigue will likely yield substantial safety benefits. The results could be used for various screening and/or enforcement strategies. These strategies could include monitoring of HOS to ensure compliance, and monitoring of the driver using technologies such as lane departure warning, eyelid-closure monitoring, and other systems.
- While complex circumstances and driver predisposition traits often contribute to driver error, the crash and inspection data analyses completed here, along with other recent studies completed by the American Trucking Research Institute, provide additional insight. These studies clearly show that drivers who were previously involved in a crash, who had prior convictions, or who were not properly licensed (invalid or expired CDLs), had a significantly higher probability than other drivers of being involved in a crash in the future. Therefore, the ability to remotely identify the driver (by obtaining the CDL number) using wireless technologies would provide the basis for a variety of enforcement strategies or concepts. For example, the CDL number could be interrogated (downloaded) well ahead of a fixed inspection station and checked against CDLIS and other databases; then an automated determination could be made as to whether to target the driver/vehicle for further inspection. More directly, if the driver were operating without a proper CDL, such information would become immediately known to the local enforcement agency, and the truck could be targeted and pulled over.
- For crashes in which the truck (and not the other vehicle) was linked to the critical causal event, vehicle defects were cited as causing the critical event in only about one out of 10 crashes. However, it is well-known that degraded braking performance, worn tires, inoperative lighting, and/or improper load securement are important secondary factors contributing to the severity of the crash. Therefore, a wireless inspection concept should target these vehicle systems. While technologies are available for electronically monitoring brakes, tires, and lighting systems, practical technology for electronically monitoring load securement is not available. Because of the wide diversity of loads, truck and trailer designs, and securement methods, it is unlikely that a practical, standardized means of monitoring load securement will be developed in the near future.

2.5 POTENTIAL IMPACTS OF MORE FREQUENT INSPECTIONS

It is clear that more frequent inspections of vehicles and drivers (along with follow-up enforcement strategies such as warnings, fines, etc.) will lead to a reduction in violations and an improvement in CMV safety. However, the level or frequency of inspections sufficient to produce a significant change in behavior on the part of operators and fleets remains to be determined. The current weight enforcement program provides important insights.

During hours of operation, a typical CMV inspection station will weigh nearly all of the trucks that pass by the station, depending to some degree on traffic density, the availability of labor, and other factors. Table 7 shows that in 2003, there were approximately 178 million weight inspections completed. This compares with about 3 million safety inspections. Many interstate trucks will be inspected for weight on nearly every trip they take. The impact on compliance levels is clear. The weight enforcement program has achieved a high degree of success with total violation rates at a very low 0.29 percent, as shown in Table 7 Also, the total weight and size violation rate is just under 2 percent for the 3 million CMVs selected for Levels I, II, or III safety inspections.

Table 7. CMV Weight Inspections

Vehicle Weight Inspections	2003
Static Weighs	82,290,618
WIM	95,078,759
All Weighs	177,369,377
# of Citations	515,587
Percent of Citations to Weighs	0.29%

The data suggests that fleet operators know there is a high probability of their vehicle being subjected to a weight check if it travels any significant distance on interstate highways. Several studies have shown that with no enforcement, weight violation rates can be as high as 20–30 percent, but with enforcement programs in place, violations drop to 1–3 percent. There is a clear economic incentive for many fleet operators to overload their trucks, yet because of the successful weight enforcement program that is in place, weight violations are arguably very low, as shown in Table 7.

For a typical fleet operator, the chances of a particular vehicle being selected for a full Level 1 safety inspection are very low when compared to the systematic weight inspection programs that are in place. As noted earlier, many mobile and fixed stations currently rely on weight as a key factor in deciding whether the vehicle requires further inspection. Therefore, for underweight trucks, the typical inspection station will rely on a random algorithm to select trucks for inspection. Anecdotal evidence indicates that many inspection sites set the random selection feature to choose approximately 5 percent of the trucks entering the weight/inspection station. Even after this filter is applied, the truck may still not be inspected, particularly if the vehicle generally appears to be in good condition as judged by the enforcement officer. Analysis of safety inspection data shows that for the industry as a whole, the average truck will undergo a full Level 1 safety inspection only about once every 3.5 years. Based on these statistics, the odds of being subjected to a safety inspection on any given trip are very low. Therefore, a sizable portion of commercial vehicle operators take the risk of not being inspected and routinely delay maintenance and/or push the limit relative to hours of service. They may rationalize their behavior in the belief that if they are selected for inspection, more often than not the violations will not result in an OOS condition, and that violations are just part of the cost of doing business. The results speak for themselves in that three out of four trucks selected for an inspection receive some type of violation, while one out of four trucks randomly selected is actually placed out of service.

The weight enforcement programs in place throughout the country offer a powerful lesson concerning inspection frequency, and clearly demonstrate the impact that increased inspections can have on modifying the behavior of fleets and operators. Implementation of a wireless inspection program which substantially increases the frequency of screening trucks for vehicle and/or driver irregularities would likely yield significant improvements in the safety of commercial vehicle operations.

2.6 PUBLIC COMMENT ON WIRELESS INSPECTIONS

On August 16, 2005, FMCSA published an RFI related to advanced concepts for commercial vehicle wireless inspections in the Federal Register (vol. 70, no. 157, Docket FMCSA-2005-22097). FMCSA invited responses, suggestions, and creative ideas on new operational concepts which would improve commercial vehicle safety inspections through more performance-based inspections.

FMCSA received 27 responses to the RFI between August 16 and October 25, 2005. One-third of the responses (nine) received came from heavy-vehicle OEMs and component/electronics suppliers. Seven industry associations, one fleet, and two State enforcement agencies also responded to the RFI. Table 8 shows a breakdown of the responses.

Table 8. Responses to the RFI

Type of Respondent	Number of Responses
Vehicle OEMs and Suppliers	9
Fleets / Motor Carriers	1
State Enforcement / Inspection Agency	2
Industry Associations / Advocacy Groups	7
Transportation Research Centers	2
Private Party / Unspecified	6
Total	27

To help focus responses, the RFI presented 14 specific questions. A complete list of these questions, along with a summary of the responses, is included in Appendix F (available upon request from the FMCSA Office of Analysis, Research and Technology).

Several respondents commented that a wireless inspection concept could include a simplified “pass/no-pass” output to allow inspectors to screen vehicles more quickly. This concept would be similar to current electronic clearance programs which pre-screen vehicles before they enter the inspection area, allowing “passed” vehicles to bypass the inspection area, with “no-pass” vehicles required to pull in for inspection.

A variation on the “pass/fail” concept submitted by the American Trucking Association (ATA) called for only “ok” messages to be sent by the vehicle. ATA’s argument was that fleets would be reluctant to embrace a concept that called for them to wirelessly transmit information that would increase their chances of being pulled over for a full inspection. They argued that a fleet would be better off sending no signal at all, as opposed to a “not ok” signal. Further, ATA argued that a simple “vehicle ok” message could be used to bypass more vehicles, thus allowing enforcement agencies to concentrate on the remaining vehicles.

Nine respondents suggested that driver HOS logs could be accurately monitored by the onboard unit. These respondents also suggested that the driver CDL and vehicle DOT numbers could be stored on the onboard unit to identify the driver and vehicle. Two of the respondents referenced the possible use of biometrics to identify drivers, as well as scanning of the driver’s CDL card when he/she entered the vehicle.

Two respondents suggested that electronic screening of vehicles could be used on non-interstate roads to catch high-risk vehicles that try to avoid passing inspection stations. A response from the Public Utilities Commission of Ohio (the agency that regulates commercial vehicles in Ohio) stated:

> *“Any increase in the volume of inspections will likely have an impact on behavior. However, there may be other factors that should also be considered that could impact behavior. For instance, if inspections can be conducted using electronic data that is quicker, easier to access, and more accurate than that which can be collected by individual inspectors, this may increase compliance since carriers will know that enforcement personnel have better tools to determine if a violation is occurring. Also, enhancing the ability to more easily conduct vehicle inspections on other non-interstate roads where inspection facilities are not located may help to catch those who currently attempt to avoid mainstream inspection facilities, which may increase compliance too.”*

In general, the comments received from the RFI provided valuable insight into the requirements and thoughts of the motor carrier industry on possible wireless inspection alternatives. These comments were taken into consideration as part of this analysis of the requirements for wireless inspections.

2.7 STATE ENFORCEMENT AGENCY SURVEYS

In addition to the RFI process, the Study Team also specifically targeted State-based CMV enforcement agencies for comments and suggestions related to a wireless inspection concept. Several State inspection stations were visited. Wireless inspection presentations were made at two industry meetings, one hosted by TMC) and the other by CVSA.

The results of discussions with State inspectors yielded the following observations and recommendations:

- To be truly valuable, a wireless inspection concept should facilitate a substantial increase in the number of inspections that can be completed.
- Onboard sensors should augment accuracy and efficiency of traditional Level 1 inspections.

- Tamper resistance and security of data transmissions must be ensured.
- Concepts should target those portions of the CMV population that are not currently being inspected or are underinspected:
  - Carriers and drivers who routinely select bypass routes
  - Straight trucks
  - Local and/or intrastate trucks
- Diagnostics and associated data to be transmitted wirelessly should target vehicle components and operational parameters that are linked to vehicle accidents and high violation rates.

Several enforcement officers at the State level were interviewed, as were State administrators responsible for overseeing State inspection programs. When asked what information they would like to see collected on vehicles as a means of improving either the screening process or the inspection itself, they gave responses that were consistent and focused on the following information (not listed in order of importance):

- Advanced message that contains the USDOT number to check carrier history
- Advanced message that contains the CDL information to check status of credentials
- Advanced message that contains the VIN or other vehicle identifier information to check results of last inspection
- Advanced message that provides electronic HOS record
- Brake diagnostics data
- Tire diagnostic data
- Advanced information that relates to size and weight

2.8 SUMMARY OF REQUIREMENTS ANALYSIS

Based on work to date, the high-level requirements for a wireless commercial vehicle inspection concept should focus on gathering data related to the brakes, tires, lighting systems, HOS, CDL information, carrier identity, and VIN. All of this information already exists on the vehicle via discrete sensor systems or electronic control modules. By using conventional technologies, it could be electronically linked to the vehicle’s serial databus for subsequent transmission by an onboard wireless communications module. This information, when combined with the historical information already available on carriers and drivers and accessible via ISS, CDLIS, or other State databases, would provide the enforcement community with a very powerful decision support tool for screening vehicles and/or implementing virtual, automated wireless inspection sites.

It should be understood that while the raw data exists on the vehicle, there may be considerable work and consensus-building required to develop “pass/fail” or rating criteria based on new electronic diagnostic information. The technical and regulatory work to be completed would be similar in concept to that which supported the development of emission inspection protocols as part of the Onboard Diagnostics process implemented by EPA.

3.0 DEVELOP ALTERNATIVE CONCEPTS OF OPERATION

Under this Task, alternative concepts of operation were developed that were differentiated based primarily on the venue and methods through which information is exchanged with the vehicle. Concepts examined included:

1. Enhanced Screening at Existing Fixed Facilities
2. Virtual, Unmanned Inspection Stations
3. Mobile Inspection Units
4. Ubiquitous Inspection Concept
5. Kiosk Self-Inspection Concept
6. Non-Cooperative Inspection Concept *(i.e., conventional, non-wireless inspections using advanced infrastructure-based sensing equipment)*

With the exception of the last concept, all would rely on the same basic modifications to the onboard electronic architecture to support the wireless transfer of information to and from the vehicle. The Wireless Communication Control Module would become the core of the system. Functionally, this module would consist of a simple application processor with moderate memory requirements for storing the SDMS (i.e., fault codes, HOS data, etc.). The application processor would assemble the electronic data from various subsystems and discrete inputs, and would perform any formatting of the data necessary for transmission. A high-level schematic of vehicle modifications needed to support a generalized wireless inspection concept is shown in Figure 7.

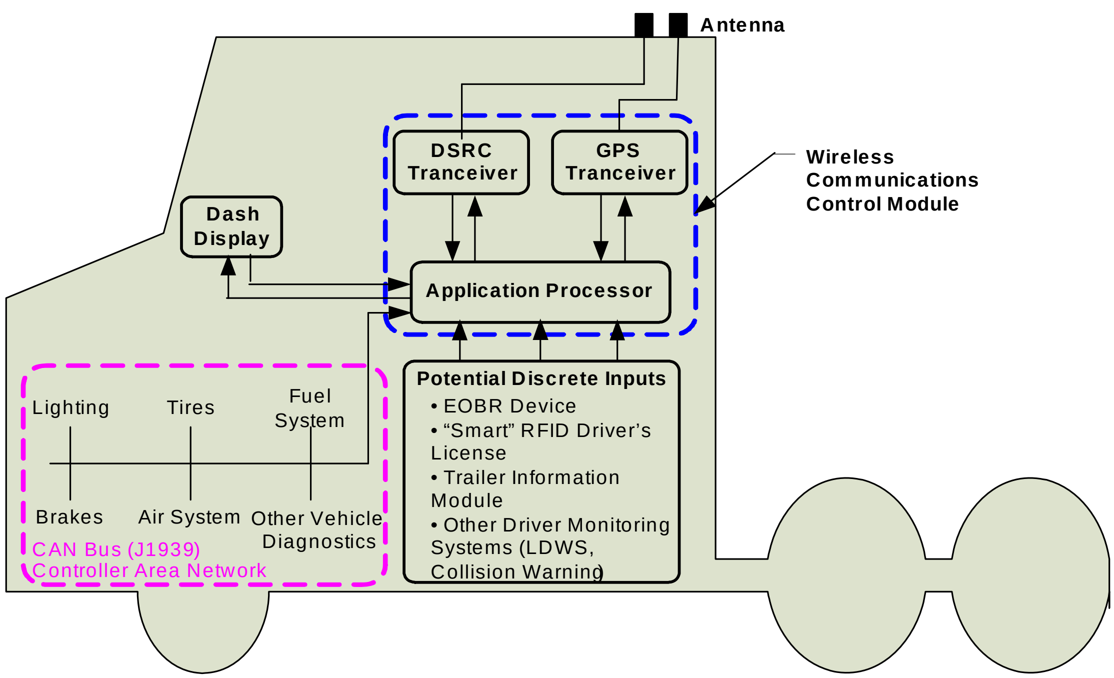


Figure 7. High-Level Vehicle Modifications to Support a Wireless Data Transfer

Instead of transmitting raw sensor data, the application processor would be programmed to analyze data (such as comparing sensor measurements against pre-set limits) to determine whether “pass,” “fail,” or other types of messages should be transmitted. Depending on concept requirements, the application processor could also assemble vehicle or driver performance histograms or other summary statistics from various input sensors. For example, the unit could be programmed to record the number of hard-braking events that occurred during various time or mileage histories. It would also be comparatively simple to include EOBR functionality in the application processor if appropriately programmed.

The Wireless Communications Control Module would also contain the DSRC (5.9 GHz) radio needed to transmit and receive messages. Again, depending on the concept of operations, the wireless control module would include an integrated GPS module, since location data would be needed to support HOS recording as well as other functions. The Wireless Communications Module would be linked to a dash module in order to display the status of various systems as well as messages sent or received from the infrastructure. It is important to understand that the onboard architecture shown in Figure 7 is notional. In reality, truck manufacturers would implement the required functionality as cost-effectively as possible. The manner in which GPS, DSRC radio, EOBR, and application-processing modules are physically combined and integrated will probably vary among manufacturers.

Each of the six venue-based concepts for collecting wireless data from the CMVs is described in the following sections.

3.1 ENHANCED SCREENING AT EXISTING FIXED FACILITIES

This concept focuses on the use of a conventional fixed-facility inspection site with advanced information about the safety status of an approaching vehicle that will determine whether the vehicle must pull into the facility for a full Level 1 inspection. This concept would enable real-time or near-real-time information about the safety condition of the vehicle and driver to be relayed to the station.

The technologies and components needed to support this concept would be packaged in fixed installations called enhanced screening stations (ESS) and would be located approximately 1–2 miles before weigh stations (see Figure 8). This concept focuses on improving the efficiency of the pre-screening process by combining identification data used to retrieve historical safety data (such as existing pre-screening systems) with actual real-time data about the vehicle maintenance and/or driver performance. As this concept is refined further, it could automatically identify noncompliant vehicles and direct them to be inspected at weigh stations, or, as confidence in the accuracy of the diagnostic systems becomes established, it could directly issue citations.

3.2 VIRTUAL, UNMANNED INSPECTION STATIONS

The virtual inspection concept is a derivative of the enhanced screening concept. However, it eliminates the need to be located near existing fixed-facility stations. An automated, unmanned inspection station (a virtual inspection station or VIS) could be located anywhere on the highway system and could incorporate short-range wireless communication to interrogate and receive the

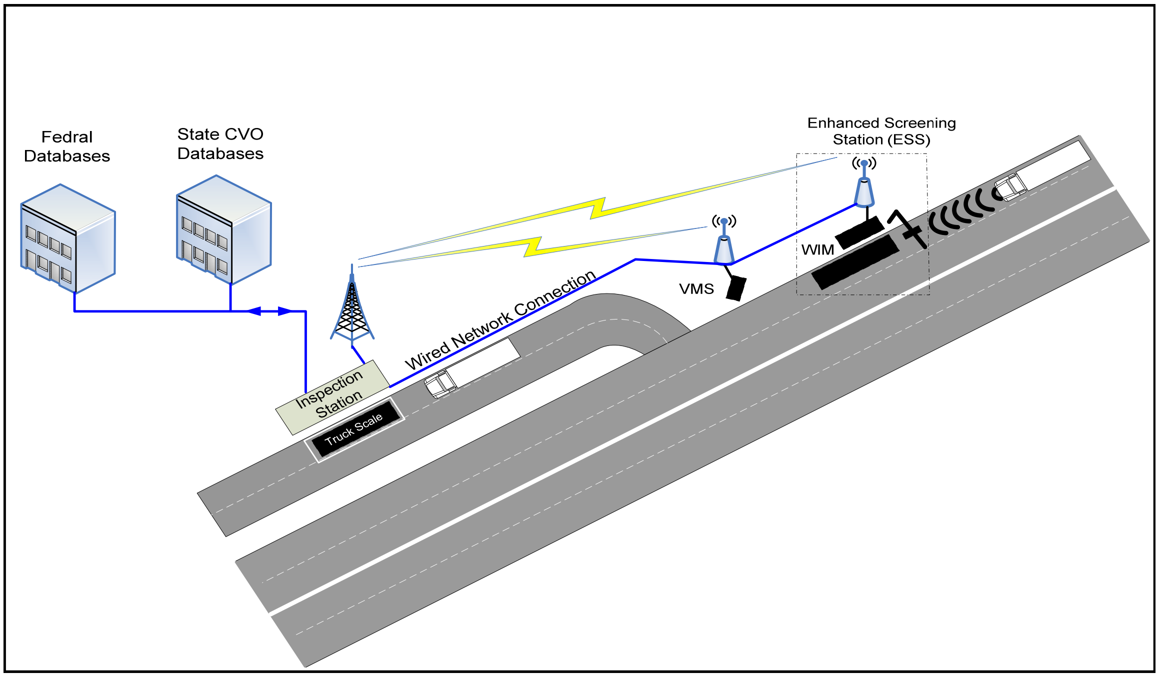


Figure 8. Enhanced Screening Concept

vehicle's SDMS while it is traveling at normal highway speeds. In addition, the VIS would include a WIM scale and could also include additional non-cooperative diagnostic technologies such as digital cameras for recording license plates numbers and/or infrared brake detection. Unlike the enhanced screening concept, however, the data gathered would be used primarily to issue warnings and/or citations directly to the carrier/operator via mail or email, rather than for supporting decisions to inspect or bypass the station. The data collected would also be used to update State and Federal CVO safety and operations database, and the results could be used to update SafeStat scores. Since the largest part of in inspection facility's operating cost is labor, this concept provides for the cost-effective expansion of inspection points and would therefore increase the probability and frequency of CMV inspections.

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3.4 MOBILE INSPECTION UNITS

Currently, mobile inspection stations are vehicles equipped with portable scales and other equipment needed to perform a roadside inspection. They offer CMV enforcement personnel the ability to inspect vehicles that would not routinely pass by a fixed station or that purposely avoid such stations. These mobile inspection units typically include the following capabilities:

- Portable scales
- Wireless access to carrier, driver, and vehicle licensing and inspection databases (via SAFETYNET, CDLIS, MCMIS, and other , State-based IT support systems described in Task 2)
- Tools and equipment needed to perform a Level 2 or 3 safety inspection

Numerous States are currently using mobile inspection units in addition to fixed inspection sites, and some States use only mobile inspections, with no fixed inspection sites. Mobile inspection units provide a flexible method for locating vehicle inspection points, and make it possible for enforcement personnel to adjust the geographic focus of inspection efforts. Such strategies are particularly effective for targeting inspection of trucks that may not normally pass by fixed inspection sites, or may use a convenient bypass route around a permanent fixed inspection site.

Under this concept, both the commercial vehicle and the police vehicle would be equipped with compatible or interoperable wireless short-range communication technology. When a police vehicle approached a moving or stationary commercial vehicle, the enforcement officer could electronically query/poll the vehicle and request an inspection file or SDMS. The SDMS would be transmitted to a processing unit on- board the police vehicle that contained evaluation and analysis algorithms similar to those that would be employed at a fixed site under the enhanced screening concept. It is also assumed that the mobile unit or police vehicle would have wireless access to SafeStat scores and other State and Federal databases that contain information on credentials, permits, taxes, and fees, and other historical data that would be needed by the officer to help make a determination as to whether to pull the vehicle over for additional visual and manual inspection. Additional application programming work would be required to refine and synthesize the results of the safety evaluation so that they could be conveniently viewed by the officer on an onboard display/reader in the police vehicle. For example, the onboard transceiver in the police vehicle might initially display high-level results from the SDMS download, but also include menu options that would allow the officer to quickly drill down into the data. SafeStat scores might initially be displayed, followed by summary information related to the real-time safety data collected via the SDMS. The enforcement officer would be able to pull this vehicle over based on the information provided.

3.5 UBIQUITOUS INSPECTION CONCEPT

This concept is focused on leveraging vehicle monitoring and diagnostic service offerings currently being implemented by selected commercial telematic service providers such as Qualcomm, PeopleNet, Orbcomm, and others. Such companies are beginning to offer option packages for a fixed monthly fee that would equip vehicles with onboard technology capable of collecting and storing various diagnostic and fault code data available on the vehicle's serial databus network. Some systems also allow for monitoring and recording the output of other optional electronic systems such as electronic HOS recorders and lane tracking, collision warning, and tire pressure monitoring systems. Normally, the carrier will work with its telematic service provider to determine:

- The specific data to collected and the optional driver and/or vehicle monitoring systems that should be added to the vehicle (if any)
- The various rules for when and where such data should be downloaded

For example, some carriers may only wish to periodically collect vehicle maintenance information, while others will want to focus on monitoring driver performance parameters. Also, some carriers may wish to collect such information based on a fixed time interval (perhaps once a day), while others may choose to collect data only on an ad hoc basis or when some pre-determined condition or threshold is exceeded. For example, a carrier may wish to be notified and have various operating parameters recorded only when vehicle speed exceeds a certain limit, or when an ABS event takes place. Additionally, since virtually all telematic service providers offer vehicle location capability, carriers may wish to have vehicle and/or driver diagnostic data communicated or downloaded using location-based rules.

Under the ubiquitous inspection concept, the SDMS containing various vehicle health and/or driver performance parameters would be shared with the State CMV enforcement agency whenever such data was downloaded by the telematic service provider, based on its contract with the customer. Alternatively, the enforcement agency could require the telematic service provider and carrier to gather and download an SDMS based on:

- Regulated conditions (such as when a vehicle is in the vicinity of an inspection station, or perhaps when a vehicle is entering a new State)
- A simple random querying of vehicles equipped with such telematic monitoring and communications capability

After receiving the SDMS, the telematic service provider would forward the information to the enforcement agency in the most cost-effective way (probably using traditional landline connections). The information would then be analyzed to determine safety conditions (most likely using automated algorithms) and an appropriate message/instruction set would be sent back to the telematic service provider by the enforcement agency. The telematic service provider would then relay the message to the vehicle via satellite or cellular communications. Such messages might call for the vehicle to pull over at the next inspection station, authorize the vehicle to bypass the next station, or issue other warnings and advisory messages.

Carriers would need to voluntarily participate in the program and instruct their telematic service providers to forward a copy of SDMS to the enforcement agency, or a regulatory framework would have to be developed that would mandate carriers having long-distance telematic capability to comply with programmed and/or ad hoc requests from the Government or enforcement agency for the SDMS.

A robust and sophisticated communications and Information Technology plan would need to be established for backhaul communications and IT systems. The backhaul network would enable telematic service providers to quickly and reliably transfer data collected from specific vehicles not only to the appropriate enforcement agency having jurisdiction, but also to the specific inspection facility that is closest to, and in the direction of travel of, the vehicle being monitored. It is assumed that the telematic service provider would interface with the enforcement agency as well as with FMCSA, using access points available either through CVISN and/or COMPASS networks. The concept would call for the telematic service provider to electronically download its inspection data into an ASPEN-like program that would then automatically forward the data to SAFETYNET.

An overview of the information flow and processes involved in this concept is shown in Figure 9.

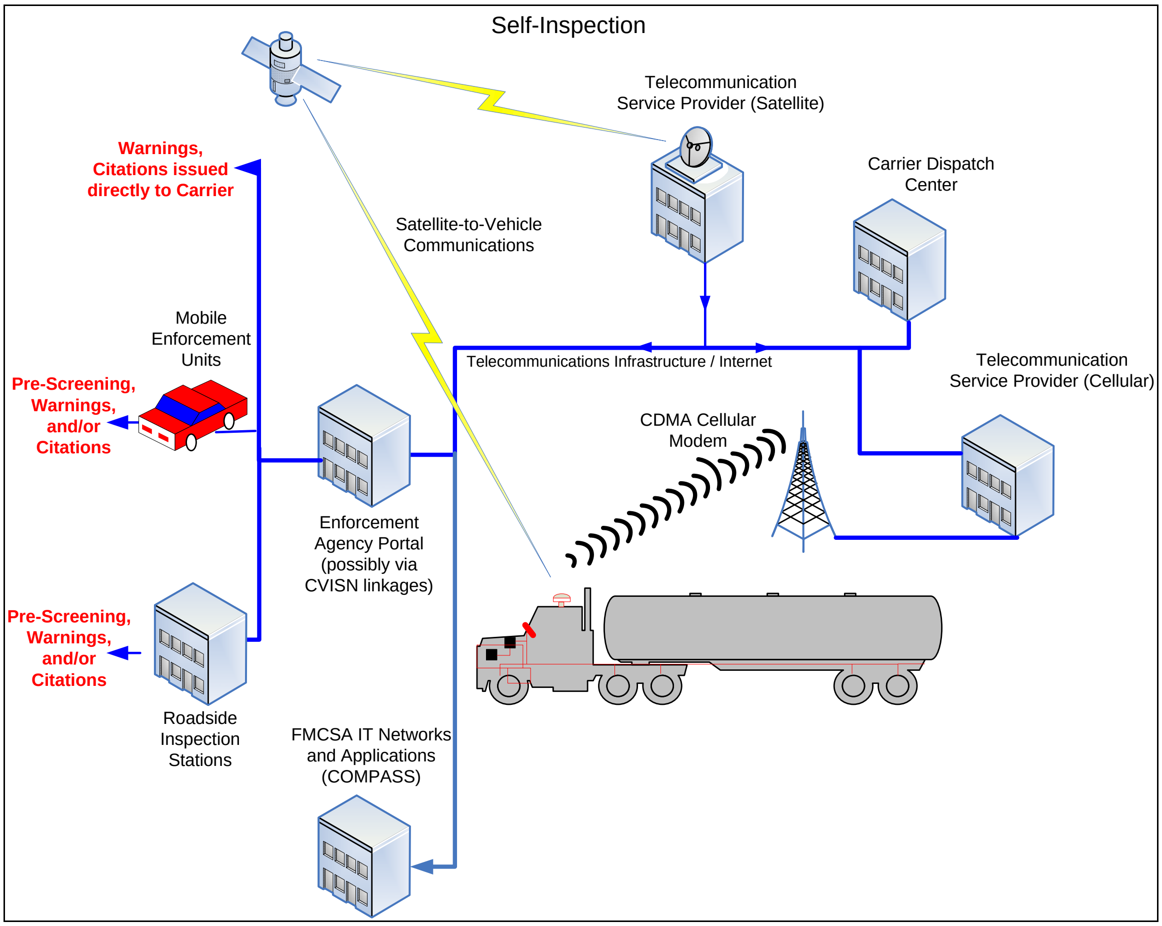

Figure 9. Ubiquitous Inspection Concept

The primary advantage of this concept is that it leverages communications and monitoring equipment already onboard a large number of vehicles (approximately 500,000) that are using long-distance telematic services. For these fleets and vehicles, little additional equipment would need to be installed on the vehicle. Also, this concept focuses on simply requiring or otherwise encouraging the sharing of this data with FMCSA and with the local enforcement agency. The incentive for equipped vehicles would be the ability to bypass inspection stations without the need to purchase and install RFID tags from organizations like Pre-Pass or NorPass.

Challenges include the following privacy and institutional issues, costs, and communication system and IT complexities:

- **Privacy and Institutional Issues**: This concept could allow the Government or State enforcement agencies to monitor HOS, driver performance, and vehicle condition on an almost-continuous basis, or to be instantly warned of violation conditions, based on certain triggers and thresholds being exceeded. A large percentage of fleets will be concerned about the level of oversight that the Government would acquire if this concept were applied.
- **Cost**: Data transmissions using long-distance satellite or even cellular communication media are expensive compared to short-range communication solutions. Satellite and cellular communications include significant per-transaction costs and/or fixed monthly service fees. The total costs of such transmissions to support various types of vehicle monitoring will need to be investigated, but current pricing at the time of this research is in the range of $25–$75 per month. The Government or local enforcement agency having jurisdiction would essentially become a third-party customer of the telematic service provider, and would incur a monthly service fee for the two-way communications established with the commercial motor vehicle population (i.e., the costs that would be incurred for downloading and uploading messages to vehicles). On the other hand, with short-range communication concepts, there are no transaction costs once the capital costs for the onboard and wayside equipment have been covered.
- **IT and Communications System Complexities**: The landline communications network and the information processing and database systems needed to support this concept are somewhat complex. This is partly due to the fact that the telematic service provider is a go-between, which doubles the number of messages as compared to a more direct short-range communications-based concept. The network complexity associated with the concept may be able to be simplified by having the telematic service provider act as an agent of the Government, but this solution may result in increased risk associated with ensuring the integrity and control of proprietary safety data.

3.6 KIOSK SELF-INSPECTION CONCEPT

All of the previously described concepts yield control of the time and location of wireless inspections to the enforcement agency having jurisdiction. The kiosk self-inspection concept is unique in that the inspection or downloading of the SDMS is performed at times and locations convenient to the driver. This concept focuses on the portion of the market that would be most skeptical or concerned about giving up control of various vehicle maintenance and operating data. However, these drivers would also like to participate in programs that might allow them to conveniently bypass inspection stations. The target market would most likely be smaller fleets and/or owner-operators.

The self-inspection kiosk is a stand-alone device or station that would consist of a screen and terminal similar to those used by banks in the form of automated teller machines (ATMs). The terminal would provide a means for the driver to enter information such as his driver's license number, USDOT number, and license plate number. The kiosk would have the capability to scan this information if it were available in bar code and/or magnetic strip format. The kiosk would also be equipped with a means to wirelessly communicate with the truck (probably using currently available WiFi or Bluetooth technology) to pull safety-related information from onboard systems and sensors. The driver's HOS log could also be downloaded wirelessly and checked electronically. The key to this approach is that not only could the kiosks be placed at locations convenient to the driver, but the inspections could be performed when the truck is off the road. Possible locations include fueling stations, truck stops, and rest areas.

The concept requires the driver to pull up to an inspection kiosk, enter in the required information, allow the safety inspection data to be downloaded from the truck, and wait for the results. Upon confirmation of a "passing grade," for driver and vehicle, the kiosk could issue a decal or possibly an inexpensive passive RFID tag the driver could display or mount on the outside of the vehicle; display of that decal or tag would allow the driver to bypass inspection stations. The data generated by the self-inspection kiosk would also be made available to the local enforcement agency, as well as to Federal databases (e.g., MCMIS).

There are several advantages to the kiosk self-inspection concept, including:

- Decentralized safety inspections that would reduce congestion at weigh stations
- Driver ownership of, and buy-in to, the vehicle safety inspection process

Challenges in implementing this concept include:

- Capital and maintenance costs associated with kiosks
- Integrating data from the kiosks with existing fixed stations would require stations to be equipped with an RFID reader and/or an optical character recognition system to positively ID the truck
- Particular concern for potential tampering and fraud related to falsifying of decals, electronic tags, and/or other documentation

3.7 NON-COOPERATIVE INSPECTION CONCEPT

Concepts 1–5 rely on technical cooperation between the commercial vehicle and the roadside for wirelessly downloading self-diagnostic safety data. Whether such concepts are deployed though market-based incentives or are regulated, there is still technical cooperation between the vehicle and the off-board reader device. If, however, such concepts become impractical because of various institutional, cost, political, and/or policy concerns, then advanced non-contact, non-cooperative technologies for assessing the condition of the vehicle might be employed to help automate and speed up the inspection process. The term "non-cooperative" as used here means that it is not necessary for the vehicle to participate (or cooperate) in facilitating the advanced/remote diagnostic procedures.

The non-cooperative inspection systems could be integrated with any existing roadside inspection station and might consist of the following elements:

- WIM sensing system
- Automatic vehicle identification (AVI) equipment
- Roadside message displays
- Infrared inspection system (IRIS)

Other inspection equipment, such as performance-based brake testers (PBBTs), acoustic sensors, and/or gas sniffer sensors, could be added to the inspection area. The screening system does not require that special equipment be installed on vehicles, nor does it require any feedback from vehicles in order to operate.

The advantage of this concept is that it can be readily implemented by State CMV enforcement agencies, provided sufficient funds are made available. The disadvantages, however, are that such a concept would not significantly increase the number of inspections that could be completed, nor would it allow for the real-time identification of the driver through the downloading of the CDL number.

4.0 CONCEPT EVALUATION

As initially envisioned, Task 4 was to have focused on evaluating each of the concepts (developed in Task 3) based on cost, safety benefits, operational considerations, and institutional deployment issues. During the assignment, however, the Project Team concluded that no single deployment concept was optimal for all operating environments. Rather, an optimal deployment of wireless inspection technology would more likely involve utilization of multiple venue-based concepts (e.g., fixed stations, mobile units, virtual stations, etc.) tailored to the specific needs and operating environments of each State. To proceed with Task 4, alternative wireless inspection concepts were redefined based on the specific types of information to be collected, rather than on the venue/processes for collecting it. The new concepts developed represented a range of complexity, costs-to-implement, and potential safety benefits. The six new SDMS concepts are summarized in Table 9.

Table 9. Alternative Wireless Inspection Concepts Based on Safety Data Message Set (SDMS) Content

SDMS Alternative	Key Output Data Collected	Required Onboard Hardware and Modifications
1 Vehicle-Basic	Currently or readily available fault code information on the J1939 network related to brakes, transmission, engine, electrical and lighting system, and other electronic components.	DSRC Transceiver with integrated data storage buffer and operating system for storing and staging fault code and ID data for wireless transmission.
2 Vehicle-Enhanced	As above, but includes specialized diagnostic data for brakes, tires, and lighting systems.	As above but includes Tire Pressure Monitoring and Brake Performance Diagnostic systems.
3 Driver-Basic	Electronic HOS Record and CDL number of the operator.	DSRC transceiver plus an integrated EOBR, and provisions for electronically identifying driver to vehicle.
4 Driver-Enhanced	Same as 3, but includes key performance and output information from a lane departure warning or drowsy driver system.	Same as 3, but includes a Lane Departure Warning, or a Drowsy Driver System.
5 Vehicle- and Driver-Basic	1 and 3 combined.	1 and 3 combined.
6 Vehicle- and Driver-Enhanced	2 and 4 combined.	2 and 4 combined.

To complete an overall evaluation of the above concepts, the following steps were undertaken:

- **Define a National Wireless Inspection Infrastructure** that would be common to all of the proposed SDMS concepts:
  - Estimate the increased coverage implied by the hypothetical infrastructure, including additional vehicles that would be inspected and increased inspection frequency
  - Estimate the costs to implement such an infrastructure
- **Estimate costs for modifying the vehicle** to collect the information implied by each concept
- **Evaluate institutional issues,** including political, policy, and likely market acceptance differences among the concepts
- **Evaluate safety impacts**, specifically, the impact on carrier and driver behavior relative to improving maintenance and operating practices, and estimate the reduction in commercial-vehicle-related crashes, fatalities, and injuries
- **Conduct Overall SDMS Alternative Evaluation and Selection** by developing an overall cost-benefit analysis for the wireless inspection concepts, and select a most-favored SDMS alternative option for moving forward

4.1 DEFINE A NATIONAL WIRELESS INSPECTION INFRASTRUCTURE

4.1.1 Hypothetical Wireless Network Footprint

In this first step, selected concepts of operation identified in Task 3 were combined to create a hypothetical national deployment footprint of wireless inspection access points. Our goal was to develop an infrastructure with coverage such that vehicle inspections would occur with sufficient frequency to significantly change the behavior of carriers and drivers relative to safe vehicle maintenance and operating practices.

Our interviews with the enforcement community, as well as stakeholder agencies such as CVSA and ATA, indicate that States would most likely want to mix and match venues and strategies for collecting wireless data (i.e., the concepts of operation from Task 3), so that a cost-effective inspection net would be created that would:

- Reduce the ability of drivers and carriers to take bypass routes
- Place inspection sites in appropriate locations to increase the number and type of trucks that are being inspected
- Leverage the existing fixed inspection facilities
- Allow mobile commercial vehicle patrol units to wirelessly inspect trucks to fill in the gaps of coverage and augment the fixed facilities

To this end, the hypothetical implementation plan would be to establish an infrastructure that would deploy wireless inspection points at ***all*** of the current fixed inspection facilities and at numerous locations that would be somewhat closer to the centers of major metropolitan areas. These close-in inspection points would be virtual stations and would target that portion of the population that operates within 50 miles or less of their home base. A plan for supplementing this deployment strategy with additional mobile inspection units would be developed. To evaluate the overall wireless inspection concept, the following deployment plan was established:

- Twelve hundred fixed facility inspection sites would be located at all existing inspection/weigh stations and would be targeted at the current population of trucks that pass by these inspection points
- One thousand virtual inspection stations would be located strategically in and around major metropolitan areas and would be focused on intra-city trucking operations as well as intrastate trucks
- Five hundred mobile inspection vehicles would be targeted for inspecting vehicles that might regularly use bypass routes around the fixed and virtual stations

Based on the described hypothetical deployment plan, the number of inspections completed annually would increase dramatically. If a wireless inspection capability was deployed only at current fixed inspection stations, at least as many truck inspections as the current number of trucks weighed (i.e., roughly 176 million each year) would be accomplished. It should be noted that trucks are weighed only during hours in which inspection stations, portable scales, and WIMs are open. When inspection facilities are closed, vehicles are allowed to bypass. A wireless inspection concept would facilitate inspection of vehicles at these 1,200 fixed facilities 24 hours a day, 7 days a week. Therefore, a figure of 176 million inspections is a very conservative estimate if electronic inspections could be performed and citations issued even when the station is unmanned.

Strategically located virtual inspection stations would significantly increase the number of CMV inspections completed, since 65 percent of trucks operate within a 50-mile range of their home base or are straight trucks. Therefore, they rarely, if ever, receive a State safety inspection. It is possible to envision approximately 274 million inspections from the 1,000 virtual inspection stations).[*]

Currently, there are about 900 to 1,200 mobile inspection units in the United States. These inspection units perform approximately one million inspections annually. Since mobile wireless inspection units or appropriately equipped police vehicles could inspect trucks with considerably higher efficiency than a conventional mobile inspection, the 500 hypothetical mobile wireless inspection units would probably inspect at least as many trucks as the current one million mobile units. The higher efficiency would result from improved targeting of trucks and reduced time involved in completing the actual inspection, since the results of the electronic diagnosis would allow officers to pinpoint problem areas.

Based on the hypothetical wireless inspection infrastructure outlined above, there could be an estimated 450 million electronic inspections performed annually on all vehicles that passed by a wireless inspection point (i.e., fixed, virtual, or mobile). This would result in an average frequency of inspections for the average commercial vehicle of every 1,000 miles (450 million inspections per 444,400 million commercial vehicle miles). Once again, many vehicles could be electronically inspected every day.

[*]176 million inspections per 1,200 fixed stations × 1,000/1,200 virtual stations × 65 percent/35 percent.

4.1.2 Wireless Infrastructure Cost Estimates

Costs for implementing a wireless inspection concept would consist of:

- Capital and operating costs for facilities and equipment
    - Fixed and virtual facilities
    - Mobile units
- Capital and operating costs for IT and communications system enhancements
    - Federal-level enhancements
    - State-level enhancements

4.1.2.1 Facility and Equipment Costs

The cost of a wireless inspection station would likely be about the same, whether it were located at a current fixed-inspection facility or at a strategically located virtual inspection location. Costs for these various components can be estimated based on similar equipment listed in the Intelligent Transportation Systems (ITS) Benefits and Cost Database. Table 10 shows the breakdown of cost for these various components, adapted from the ITS Benefits and Cost Database.

Table 10. Fixed and Virtual Inspection Station Estimated Cost per Station[3]

Fixed/Virtual Inspection Station	Capital Cost	O&M Cost per Year
Infrastructure Modifications (radio mounting fixture)	$10K–$15K	$1K–$1.5K
Short-Range Wireless Transceiver Radio	$2K–$5K	$0.2K–$0.5K
Communications Infrastructure	$10K–$20K	$0.5K–$1K
WIM Scale	$14K–$21K	$1.4K–$2.1K
Optical Automatic Vehicle Identification	$10K–$15K	$1K–$1.5K
Total	$46K–$76K	$4.1K–$6.6K

A mobile inspection system, integrated with a patrol car or a portable trailer, would probably include a portable computer with printer and a short-range wireless transceiver radio, and would require a wireless telecommunications connection to download, record, and upload carrier, vehicle, and driver safety database records at field locations. It would also include portable scales or a portable WIM to measure vehicle and axle load.

[3] Cost estimate data adapted from the U.S. Department of Transportation, Intelligent Transportation Systems Benefits, Costs Database, ITS Joint Program Office, http://www.benefitcost.its.dot.gov/

Table 11 shows the breakdown of cost for a mobile inspection unit adapted from the ITS Benefits and Cost Database.

Table 11. Mobile Inspection Unit Estimated Cost per Unit[4]

Mobile Inspection Unit	Capital Cost	O&M Cost
Enforcement Vehicle or Trailer System	$7.5K–$9.2K	$0.44K–$0.66K
Portable Scales or Portable WIM	$4K–$8K	$0.4K–$0.8K
Total	$11.5K–$17.2K	$0.84K–$1.46K

Therefore, the total cost to build out and maintain the facilities and equipment for a wireless inspection network is shown in Table 12.

Table 12. Total Hypothetical Wireless Facilities and Equipment Costs

Hypothetical Wireless Inspection Infrastructure	Stations/Units	Capital Cost	O&M Cost
Fixed Inspection Sites	1,200	$55M–$91M	$4.9M–$7.9M
Virtual Inspection Sites	1,000	$46M–$76M	$4.1M–$6.6M
Mobile Units	500	$5.8M–$8.6M	$0.4M–$0.7M
Total	1,700	$106M–$176M	$9.4M–$15.2M

4.1.2.2 IT and Communications System Enhancements

Additional costs will be required to implement major modifications to back-office hardware and information system infrastructure to handle the inspection data and to perform enforcement of inspection violations. These costs will likely be divided among Federal agencies and States. There will also likely be an initial capital cost to make these improvements, along with the annual increase in operating and maintenance costs.

For instance, at a Federal level, even if the raw inspection data is not retained or included as part of MCMIS, it will still be necessary to expand the MCMIS database to handle summary data for the significant increase in inspections performed (i.e., from 3 million to approximately 452 million). A significant capital expenditure will be needed to upgrade the FMCSA’s Federal IT systems, possibly as an add-on or enhancement to the current COMPASS program. As the COMPASS program progresses, provisions would have to be made for the handling, storing, and mining of wireless inspections (even summary data), as well as changes to the ISS algorithms based on real-time wireless inspection data. A nationwide database will be needed to maintain records of CDL and vehicle registrations status by coordinating with State agencies. A very rough preliminary estimate for capital costs necessary for upgrading and expanding the COMPASS program is between $10 million and $15 million. An annual increase in IT operating

[4] Cost estimate data adapted from the U.S. Department of Transportation, Intelligent Transportation Systems Benefits, Costs Database, ITS Joint Program Office, http://www.benefitcost.its.dot.gov/

costs of between $1 million and $2 million has also been allowed for in order to analyze and maintain the expanded data set.

States will also need to make significant improvements in both their roadside enforcement IT applications as well as back-office CMV IT support systems. New information systems for linking VIN, USDOT number, CDL number, and license plate numbers will have to be developed and implemented. Enhancements to CDL administration, SAFETYNET support, and other licensing, insurance, and tax systems will also likely need upgrading and expansion in order to fully leverage the benefits of the wireless inspection concept. Additional coordination and integration of these systems will be required, as well as refined levying and processing systems, if an automated enforcement strategy is adopted, similar to IT and data-processing systems that support red-light-running cameras and automated speed enforcement. It is possible that these improvements and coordination would be facilitated through the CVISN program as a means to standardize systems across both the State and Federal levels. A significant initial capital expenditure would be required for improvements in each State's IT systems, perhaps between $2 million and $3 million per State ($100 million to $150 million total). Additionally, there would be increased annual IT system operating and maintenance costs for States, which is estimated at $250,000 to $500,000 per State ($12.5 million to $25 million total).

Table 13 summarizes the estimated capital and annual O&M (operation and maintenance) costs for IT system enhancements for both the Federal Government and the States.

Table 13. Information Technology Enhancement Costs

IT Enhancement Costs	Capital Cost	O&M Cost per year
Federal Level (COMPASS)	$10M–$15M	$1M–$2M
State Level (CVISN)	$100M–$150M	$12.5M–$25M
Total	$110M–$165M	$13.5M–$27M

4.1.2.3 Total Infrastructure Costs

The total costs for establishing a CMV wireless inspection infrastructure are estimated at between $216 million and $341 million, while increased operating costs are between $23 million and $42 million, as shown in Table 14.

Table 14. Total Wireless Inspection Infrastructure Costs

Infrastructure Cost	Capital Cost	O&M Cost per year
Total Facilities and Equipment	$106M–$176M	$9.4M–$15.2M
Total IT and Communication Systems	$110M–$165M	$13.5M–$27M
Total	$216M–$341M	$22.9M–$42.2M

4.2 VEHICLE MODIFICATION COSTS FOR EACH ALTERNATIVE

4.2.1 Vehicle Costs: Alternative 1—"Vehicle Basic"

A wireless inspection module that records only basic vehicle-related information would probably be similar to current in-cab ECUs, and would interface primarily with the J1939 and J1587 networks. This fundamental vehicle inspection module would record the minimum vehicle-only SDMS, including:

- Vehicle identification information
- Standard fault codes

To implement this concept, an approach similar to that adopted by the EPA for standardizing emission system fault codes could be taken. Essentially, the EPA and CARB focus on developing performance-based reporting standards for emissions-related components, and then place the burden on manufacturers to determine what faults to report and under what conditions. For example, if a particular component (such as an oxygen sensor) is out of calibration to such an extent that it degrades emission performance beyond a regulatory limit, then the manufacturer is required to determine the point at which an out-of-calibration condition becomes significant, and to report it as a fault. The USDOT could implement a similar strategy for safety-related systems. While the strategy is simple in concept, it should be recognized that substantial technical development work and testing would be required to implement safety system fault code guidelines and to link them with pass/fail inspection criteria.

It is estimated that basic vehicle-only wireless inspection module could be manufactured, integrated in the vehicle, and sold to fleets in new vehicles for between $273 and $485. Table 15 shows a breakdown of this cost.

Table 15. Incremental Vehicle Cost: "Vehicle Basic"

Inspection Module	Cost
Data Recorder Per-Unit Hardware Cost	$125–$175
Short-Range Wireless Radio Per-Unit Cost	$30–$40
Total Per-Unit Cost (including amortized tooling and software development costs)	$160–$223
OEM Vehicle Integration Costs Per Vehicle	$50–$150
Cost to Fleets (per vehicle)	$273–$485

4.2.2 Vehicle Costs: Alternative 2—"Vehicle Enhanced"

An enhanced vehicle-only inspection module would be similar to the basic vehicle-only module except that it would include additional sensors or systems for tire-pressure monitoring and for measuring brake performance. An enhanced vehicle-only inspection module would record an extensive SDMS, including:

- Vehicle identification information
- Fault codes and warnings

- Lighting faults
- Tire pressure status
- Brake performance and/or adjustment (e.g., wheel speed sensors, stroke sensors, instrumented anchor pins)

An enhanced vehicle-only wireless inspection module could be manufactured, integrated into the vehicle, and sold to fleets in new vehicles for between $1,378 and $4,320, including the advanced sensor systems. Table 16 shows a breakdown of this cost.

Table 16. Incremental Vehicle Cost: "Vehicle Enhanced"

Inspection Module	Cost
Data Recorder Per-Unit Hardware Cost	$125–$175
Short-Range Wireless Radio Per-Unit Cost	$30–$40
Brake Performance/Adjustment System	$250–$1,500
Tire Pressure Monitoring System	$500–$1,200
Total Per-Unit Cost (including amortized tooling and software development costs)	$910–$2,923
OEM Vehicle Integration Costs Per Vehicle	$150–$400
Cost to Fleets (assuming 30-percent markup)	$1,378–$4,320

4.2.3 Vehicle Costs: Alternative 3—"Driver Basic"

Alternative 3 would record a fundamental driver-centric SDMS which would include:

- Vehicle identification information (VIN)
- Driver identification information (principally, the operator's CDL number)
- HOS logs with GPS locations

Adding the capability to record a driver's HOS logs is highly variable in complexity and cost. Currently, FMCSA is researching the use of EOBRs for electronically capturing HOS logs. These EOBRs could take many forms. They could be a stand-alone module, a functionality built into the device/system from a commercial telematic company, or a portable device such as a PDA or cellular-phone-based design. Therefore, it is likely that a wireless inspection module designed to record driver identification and HOS logs could take one of two forms:

1. The inspection module could interface directly with a stand-alone EOBR and pull the log records and driver identification information from this unit.
2. The wireless inspection module could be integral with the EOBR functionality and could maintain the logbook itself, making it a single wireless inspection module with a dual function capability.

It is unclear which approach the industry might adopt, as EOBR regulations have not yet been published. The timeline, industry acceptance, EOBR design form (i.e., integrated with the vehicle or in a PDA), technical design synergies between the two devices, and cost will affect the approach finally adopted.

The two approaches vary significantly in cost, and will impact design of the wireless inspection module. If the EOBR as a stand-alone unit is chosen, then relative cost increases to the wireless inspection module would be minimal, and only an interface between the EOBR and the inspection module would be necessary. If integration of the EOBR functionality with the wireless inspection module is chosen, that could have a significant cost impact. The module would have to include capabilities to directly record information from a driver's license using bar code, magnetic strip, or RFID technology as described earlier; a GPS receiver to record location and time data in the log; and a screen or other interface with the driver to review his or her logs.

It is estimated that a basic driver-centric wireless inspection module could be manufactured, integrated in the vehicle, and sold to fleets in new vehicles for between $468 and $875. Table 17 shows a breakdown of this cost. It should be understood that these cost estimates are based on an assumption of large-scale deployment and the associated economies of scale for electronic devices.

Table 17. Incremental Vehicle Cost: "Driver Basic"

Inspection Module	Cost
Data Recorder Per-Unit Hardware Cost	$125–$175
Short-Range Wireless Radio Per-Unit Cost	$30–$40
Hours-of-Service Recording Capability Per-Unit Cost (integrated EOBR)	$50–$150
GPS Receiver Cost (integrated EOBR)	$50–$100
Total Per-Unit Cost (including amortized tooling and software development costs)	$260–$473
OEM Vehicle Integration Costs Per Vehicle	$100–$200
Cost to Fleets (assuming 30-percent markup)	$468–$875

4.2.4 Vehicle Costs: Alternative 4—"Driver Enhanced"

An enhanced driver inspection module would be similar to the basic driver module in that it would record VIN, driver identification information (CDL), and HOS logs, but it would also include capabilities to directly measure and record driver performance and fatigue. There are several commercially available technologies that can detect drowsy, distracted, or fatigued drivers.

Most use one of three monitoring methods:

- Lane position
- Driver eye
- Steering wheel position

Lane departure warning systems (LDWS) use video cameras and digital video processing to determine the location of the vehicle relative to the lane. In some systems, this data is supplemented by forward-looking radar. The digital video-processing tracks road features such as lane markings to determine the relative location of the truck. It then provides audible and/or visual alert indicators when the vehicle begins to drift out of the lane. Monitoring of lane position to detect weaving and erratic steering behavior can provide an indication of driver fatigue or inattention. Since these are video-based systems, they often have difficulty tracking during adverse conditions (e.g., white-out snowstorm, heavy and/or nighttime rain, or glare). Several companies offer LDWS.

Monitoring the behavior of a driver’s eye and eyelid is another method for drowsy-driver detection. A metric of drowsiness that has gained popularity, particularly with NHTSA, is PERCLOS, the percentage of eyelid closure over the pupil in a given period of time, reflecting slow eyelid closures rather than blinks. However, accurately measuring PERCLOS in a vehicle during operation has proven difficult. Typically, PERCLOS systems use small cameras and an infrared illumination source to pick up and discern a driver’s eye. Daytime sunlight can cause the infrared camera signal to become washed-out or less clear. These systems operate best at night. Additionally, drivers’ glasses and sunglasses can cause interference. The technology is still in development, and NHTSA is conducting research to determine the accuracy of the system.

A third type of driver performance measurement technology currently under development is based on monitoring steering wheel inputs. With this approach, empirically developed algorithms are used to analyze driver steering adjustments and to determine if there is too much or too little input/correction given the specific operating conditions. This type of technology is also still under development.

While each of these monitoring systems shows promise, extensive research, testing, and consensus- building efforts would be needed to develop standardized criteria for driver fatigue. Also, the incremental cost associated with adding such capability has yet to be established. However, current LDWS designed for CMVs sell for between $1,000 and $1,500. This figure was used as an estimate for this analysis.

It is estimated that an enhanced driver-only wireless inspection module could be manufactured, integrated in the vehicle, and sold to fleets in new vehicles for between $1,573 and $3,085. Table 18 shows a breakdown of this cost.

Table 18. Incremental Vehicle Cost: "Driver Enhanced"

Inspection Module	Cost
Data Recorder Per-Unit Hardware Cost	$125–$175
Short-Range Wireless Radio Per-Unit Cost	$30–$40
Hours-of-Service Recording Capability Per-Unit Cost	$50–$150
GPS Receiver Cost	$50–$100
Onboard Drowsy Driver-Monitoring Device (i.e., LDWS)	$800–$1,500
Total Per-Unit Cost (including amortized tooling and software development costs)	$1,060–$1,973
OEM Vehicle Integration Costs Per Vehicle	$150–$400
Cost to Fleets (assuming 30-percent markup)	$1,573–$3,085

4.2.5 Vehicle Costs: Alternative 5—"Vehicle and Driver Basic"

A combined basic vehicle-plus-driver inspection module would be the combination of Alternatives 1 and 3. This alternative would record the following parameters:

- Vehicle identification information (VIN)
- Driver identification information (CDL number)
- HOS logs with GPS locations
- Currently available vehicle fault codes

A basic vehicle-plus-driver wireless inspection module (i.e., a combination of Alternatives 1 and 3) could be manufactured, integrated in the vehicle, and sold to fleets in new vehicles for $533 to $940. Table 19 shows a breakdown of this cost.

Table 19. Incremental Vehicle Cost: "Vehicle and Driver Basic"

Inspection Module	Cost
Data Recorder Per-Unit Hardware Cost	$125–$175
Short-Range Wireless Radio Per-Unit Cost	$30–$40
Hours-of-Service Recording Capability Per-Unit Cost	$50–$150
GPS Receiver Cost	$50–$100
Total Per-Unit Cost (including amortized tooling and software development costs)	$260–$473
OEM Vehicle Integration Costs Per Vehicle	$150–$250
Cost to Fleets (assuming 30-percent markup)	$533–$940

4.2.6 Vehicle Costs: Alternative 6—"Vehicle and Driver Enhanced"

An enhanced vehicle and driver inspection module would be the combination of Alternatives 2 and 4, and would be the most extensive wireless inspection module. This alternative would record monitoring and record the following parameters:

- Vehicle identification information (VIN)
- Driver identification information (CDL number)
- HOS logs with GPS locations
- Currently available vehicle fault Codes (such as braking, electrical, powertrain, and/or lighting system faults)
- Tire pressures
- Brake adjustment and performance using dedicated sensors (i.e., stroke sensors)
- Driver performance and fatigue via LDWS

It is estimated that an enhanced vehicle and driver wireless inspection module (i.e., a combination of Alternatives 2 and 4) could be manufactured, integrated in the vehicle, and sold to fleets in new vehicles for $3,783 to $6,595. Table 20 shows a breakdown of this cost.

Table 20. Incremental Vehicle Cost: "Vehicle and Driver Enhanced"

Inspection Module	Cost
Data Recorder Per-Unit Hardware Cost	$125–$175
Short-Range Wireless Radio Per-Unit Cost	$30–$40
Hours-of-Service Recording Capability Per-Unit Cost	$50–$150
GPS Receiver Cost	$50–$100
Brake Adjustment and Defect Sensing System (i.e., MGM E-Stroke)	$1,000–$1,500
Tire Pressure Monitoring System	$500–$1,200
Onboard Drowsy Driver Monitoring Device (i.e., LDWS)	$1,000–$1,500
Total Per-Unit Cost (including amortized tooling and software development costs)	$2,760–$4,673
OEM Vehicle Integration Costs Per Vehicle	$150–$400
Cost to Fleets (assuming 30-percent markup)	$3,783–$6,595

4.2.7 Summary of Vehicle Cost Impacts for Each Concept Alternative

The low- and high-incremental vehicle cost estimates for each alternative are summarized in Table 21. These incremental cost estimates are for new vehicles that have been designed to support the data monitoring and wireless downloading capabilities required for each of the concepts. Further, the costs assume high-volume economies of scale with all new vehicles being equipped on an industry-wide basis.

Table 21. Summary of Incremental Vehicle Costs for Each SMDS Alternative Concept

Total Cost per Unit	1 Vehicle Basic	2 Vehicle Enhanced	3 Driver Basic	4 Driver Enhanced	5 Vehicle and Driver Basic	6 Vehicle and Driver Enhanced
Low	$237	$1,378	$468	$1,573	$533	$3,783
High	$485	$4,320	$876	$3,085	$940	$6,595
Average	$361	$2,849	$672	$2,329	$737	$5,189

4.2.8 Vehicle Costs: Non-Cooperative (Baseline) Alternative

In addition to the six cooperative wireless concepts previously described, one of the concepts outlined in Section 3 involves a non-cooperative approach that relies only on advanced infrastructure-based sensors. In summary, this concept would include:

- A WIM to measure vehicle and axle weights
- An AVI system using optical recognition of license plate and USDOT numbers
- An infrared brake sensor to detect significantly misadjusted or defective brakes
- Other advanced technologies, such as an acoustic sensor for detecting suspension or exhaust problems, optical or acoustic sensors for detecting tire inflation, or an electronic sniffer sensor for detecting hazardous chemical leaks or radiation

This concept of operations is not groundbreaking, since some States have already been researching and installing these technologies to screen vehicles more efficiently. It is likely that as these technologies mature, and as the enforcement community becomes comfortable with them, more States will implement them. Therefore, this alternative can be considered a baseline concept. Some of these non-cooperative technologies may eventually become more prevalent if a wireless inspection program does not move forward. Table 22 shows a breakdown of component costs, although costs were not yet available for some components that are in early stages of development.

Table 22. Non-Cooperative Alternative Cost Estimate

Fixed/Virtual Inspection Station	Capital Cost	O&M Cost per Year
Infrastructure Modifications (mounting fixtures)	$20K–$35K	$2K–$3.5K
Communications Infrastructure	$10K–$20K	$0.5K–$1K
Weigh-In-Motion Scale	$14K–$21K	$1.4K–$2.1K
Optical Automatic Vehicle Identification	$10K–$15K	$1K–$1.5K
Infrared Brake Sensing Technology	Not Available	Not Available
Acoustic Sensors for Exhaust, Suspension, and/or Tire Failures	Not Available	Not Available
Sniffer Sensors for Hazardous Gas and Radiation Detection	Not Available	Not Available

4.3 INSTITUTIONAL AND DEPLOYMENT ISSUES FOR ALTERNATIVE WIRELESS INSPECTION CONCEPTS

All six of the wireless inspection alternatives described herein (“vehicle basic,” “driver basic,” “vehicle enhanced,” “driver enhanced,” “vehicle and driver basic,” and “vehicle and driver enhanced”) are technologically feasible using readily available components, sensors, and communications technology. The costs of implementation, safety benefits, and institutional issues, however, will differentiate the alternatives. Institutional issues include policy, political, and market acceptance. These institutional and deployment barriers are often the most important considerations to be addressed before moving forward.

In general, all six of the SDMS alternatives will face similar challenges relative to institutional deployment issues. Some types of direct or indirect Federal Government initiative (e.g., regulations, standards development, public-private partnerships, and/or funding support of programs such as CVISN) will be needed to spur widespread adoption by the industry. All of these options focus on wirelessly extracting information that could be used for issuing violations and/or impacting Safety Evaluation Area (SEA) scores. They could even be used for litigation purposes, should a vehicle become involved in a crash just after undergoing a wireless inspection. To this extent, fleets will not be voluntarily supportive unless operational and economic benefits can be demonstrated. Existing electronic pre-screening programs already allow CMVs to bypass inspection stations in many States, thus undercutting this potential benefit of wireless inspections. In other words, the de facto standard of information needed to allow a truck to bypass a station has been established as the simple transmission of the carrier’s USDOT number. If bypassing inspection stations is to be used as the carrot for fleets to adopt wireless inspection technology, then limitations inherent in current pre-screening programs will need to be highlighted. States will need to be encouraged to require more real-time information to be transmitted before allowing a vehicle to bypass the inspection station.

Given the above understanding, there are still some differences in the institutional and market acceptance challenges that the SDMS alternatives would have to overcome.

4.3.1 Institutional Challenges for Extracting Vehicle-Based Data

Those alternatives that would extract only vehicle-based information (Alternatives 1 and 2) would probably face fewer challenges in the marketplace. Alternative 1 (“vehicle basic”) focuses on extracting only information that is already available on the J1939 network. To this extent, the SDMS associated with this alternative would make available the same type of information that could be collected by conventional diagnostic tools if the vehicle were stationary. It is envisioned that the message set would also include the VIN, since this information is readily available on the vehicle databus. It could be argued that the SDMS for Alternative 1 would simply allow the enforcement agency to determine more conveniently whether or not there are major faults present on the vehicle. It would also allow the enforcement agency to more conveniently and positively identify the vehicle (using the VIN). Conceptually, gathering such information is no different than identifying the vehicle using optical character recognition of the license plate and/or USDOT number (a practice which is already common and accepted by the marketplace).

The SDMS associated with Alternative 2 (“vehicle enhanced”), on the other hand, would be more difficult to implement from a technical and policy perspective. As reviewed earlier, standard methods, performance metrics, and failure criteria have not been established for tire-pressure monitoring and/or brake diagnostic systems. It may be possible to establish such metrics based on current measurement and failure criteria associated with a Level 1 inspection. However, it is possible, because of the manner in which the diagnostic technologies may be implemented, that one-for-one use of existing failure criteria would not be applicable, and that new criteria would need to be developed. For example, violations are currently issued for individual brake assemblies that are too far out of adjustment. While automated stroke measurement systems exist, other systems that rely more directly on braking force (or even monitoring of wheel speeds) may produce even better diagnostics than stroke sensors, although no standard criteria or measurements criteria yet exist. Even if brake-stroke sensing systems were made standard, the details of how such a system would work, the accuracy requirements, and the reporting requirements would still need to be worked out. While automated diagnostic systems for brakes and tires are available and reliable, the process of agreeing on standards for issuing violations using these new systems would be challenging. Given the challenges FMCSA is already facing concerning use of PBBTs for determining brake system compliance, standards based on even newer technologies would be quite challenging.

4.3.2 Institutional Challenges for Extracting Driver-Based Data

The information to be gathered under Alternatives 3–6 includes gathering driver-related data, which by definition will be more institutionally difficult since personal privacy issues will arise. However, Alternative 3 (“driver basic”) and Alternative 5 (“vehicle and driver basic”) focus only on gathering driver data that would already be available to a roadside inspector—specifically, the operator’s CDL number and his/her HOS logbook information. It could be argued that gathering such information wirelessly is simply a more convenient and accurate means of performing this function. While there are no doubt substantial institutional and policy challenges associated with gathering even basic driver information wirelessly, the fact that such information is already regularly requested by enforcement agencies, and routinely given by fleet operators, suggests that such challenges can be met. In many respects, gathering HOS data wirelessly is simply a technical extension of EOBR regulatory actions that are under consideration. (EOBRs are already making available the electronic HOS data that would become part of the SDMS, so the only added twist is that with Alternatives 3 and 5, such information would be extracted more conveniently through wireless communications technology.)

Alternatives 4 (“driver enhanced”) and 6 (“vehicle and driver enhanced”) both call for the addition of equipment that would directly monitor driver performance. As reviewed earlier, such equipment may include lane departure warning and/or drowsy-driver monitoring systems. There will be major deployment challenges on two levels for including the output of such systems in an SDMS. The first involves standardizing functional requirements and performance metrics, and developing violation criteria for these types of comparatively new driver monitoring systems. There would need to be large, sustained research programs and field tests before Government and industry could arrive at some consensus on the output format from such systems, the accuracy and reliability requirements, and most important, the measurement levels that would lead to various type of violations. These challenges are similar to those of the advanced vehicle monitoring systems described for SDMS Alternative 2, although the challenges are even more severe since the systems involve monitoring drivers to determine whether they are performing acceptably, rather than monitoring a comparatively simple mechanical system (such as brakes and tires).

Alternatives 4 and 6 would also face major institutional, policy, and political challenges related to concerns over operator privacy, use of the data for tort litigation, and general industry and driver acceptance. The institutional challenges overlap with the technical challenges (i.e., the lack of standardization) described above. Fleets and drivers would have major concerns that the output of these driver-monitoring systems could be used against them—not necessarily for issuing violations or fines, but rather for lawsuits against them in crash cases. Interviews conducted with fleets and fleet associations suggest that their real concern is not that the systems may result in increased fines, or may highlight poor operator performance (fleet managers and Government are on the same side of this issue), but that the systems will be collecting data that may get misinterpreted by courts and may substantially increase their liability. The trucking industry would be concerned that similar information would not be available from the passenger cars involved in the accident. As an operations manager at a large TL fleet stated, "We will collect and report such data as soon as the same information is available about the passenger car driver. Otherwise, we are at a disadvantage."

Driver-monitoring systems (particularly collision warning, rollover, and LDWS) are enjoying a moderate degree of success in the marketplace because they are being positioned as driver aids, and the output data is generally not being recorded by most fleets. Indeed, one manufacturer of LDWS recently removed such recording features from its product in order to improve customer acceptance. A program to standardize the output of such devices among all manufacturers, record the information, and then permit State enforcement agencies to wirelessly access the information at any time or location would face major opposition.

Based on the Research Team's interviews with industry stakeholders, and a review of relevant research in this area, a summary of how the six SDMS alternatives rank relative to institutional issues is shown in Table 23.

Table 23. Institutional and Deployment Challenges for SDMS Alternatives

SDMS Alternative	Data Collected	Ranking
1) Vehicle Basic	Readily available fault code data	3
2) Vehicle Enhanced	As above + brake, tire, and lighting system data	1
3) Driver Basic	CDL number + HOS logbook data	2
4) Driver Enhanced	As above + driver performance measurements	1
5) Vehicle + Driver Basic	1 + 3	2
6) Vehicle + Driver Enhanced	2 + 4	0
Baseline / Non-Cooperative	External Roadside Sensors Only	4

Key to Rankings: 4 = Little/No Institutional and Deployment Challenges
1 = Severe Institutional and Deployment Challenges

4.4 SAFETY BENEFITS OF WIRELESS INSPECTION CONCEPTS

Safety benefits from implementing the various alternative concepts are based on the premise that a substantial increase in inspection frequency, together with the specific information collected under each alternative, would result in changing fleet and driver behavior. Specifically, frequent wireless inspections of vehicle-based systems (e.g., tires, brakes, lights) would hypothetically result in discovery and assessment of violations that would otherwise go undetected. This enforcement activity would impact carrier SEA scores, thus increasing the carrier's cost of doing business through increased fines, increased insurance, and reduced competitiveness and attractiveness to shippers (for for-hire carriers). Fleets and carriers would therefore act in a variety of ways to improve their vehicle maintenance practices, including retaining more and better mechanics, investing in more and more advanced diagnostic equipment, implementing improved in-house vehicle inspection and quality control programs, and working with drivers to enhance pre-trip inspections.

Similarly, if the operator's daily log were accessed and analyzed wirelessly on virtually every significant trip taken (as it would be, based on the wireless inspection infrastructure described in earlier sections), then enforcement agencies would immediately know of violations of HOS and the fleet operator/driver would be caught. Aside from the possibility of tampering with the EOBR and integrated wireless equipment, it could be argued that abuse or disregard of HOS rules would be nearly eliminated and compliance levels would in the long run likely approach 95–100 percent, as the nation's fleets transitioned to wireless inspection technology. Essentially, a wireless commercial vehicle inspection program would bring about a dramatic reduction in violation levels for those systems and operations that were being monitored.

If wireless inspection technology were mandated for new vehicles beginning in a given year, the large majority of in-use vehicles would be equipped within less than 10 years, as the turnover rate for heavy trucks is quite high, with many large carriers turning vehicles over every 4–5 years. To evaluate the safety benefits of the SDMS alternatives, full market penetration is assumed. That is, the analysis represents the long-term benefits accruing if a wireless inspection program were implemented. With this background, safety benefits for each of the SDMS alternatives are examined in the following sections.

4.4.1 Safety Benefits: Alternative 1—Vehicle Basic

Under SDMS Alternative 1, vehicle diagnostic data to be downloaded would be limited to fault code data on major subsystems such as brakes, engine, transmission, and lighting systems. The impact of Alternative 1 would be to nearly eliminate cases in which a truck is being driven with a significant defect in any of these systems. Operators would know that if a dash light (or message) were being presented to them showing a malfunction in the brakes, lights, engine, or transmission, this same fault information would be transmitted to the local enforcement agency, and that their vehicle would most likely be targeted for a more complete inspection.

To accomplish this, it would be necessary to develop a complete regulatory approach. For example, enforcement strategies might call for initially issuing warnings for vehicle defects and then allowing fleets a specified amount of time to make repairs. If the repairs were not made, or multiple warnings were given, then fines might be assessed. Essentially, Alternative 1 would strongly encourage fleets and drivers to investigate and repair malfunctions of major vehicle safety systems.

Overall, it is likely that this alternative would have only a marginal impact on safety. First, our interviews with fleets indicated that drivers and fleets already act fairly quickly when a "check engine" or similar message is illuminated and presented to the driver. Second, crash data shows that comparatively few crashes are directly caused by vehicle mechanical problems.

Given the type of diagnostic data that would be efficiently monitored under Alternative 1, the degree to which fleets and operators would be motivated to improve their overall vehicle maintenance practices is unclear. Although, under this particular alternative, detailed diagnostic information would not be available to the enforcement agencies on many systems (e.g., tires, suspension, steering, load securement, etc.), there still may be a "halo" effect from monitoring the vehicle's databus for general system diagnostic information. The electronic systems on commercial trucks are sufficiently complex that many fleets are simply not sure exactly what can and cannot be reported on the vehicle's network databus. Therefore, even though under Alternative 1, direct monitoring of tire, suspension, or steering system performance may not be included, fleets may still improve maintenance in these areas. Some fleets may choose to improve their maintenance and vehicle inspection programs in all areas simply to ensure that their vehicles are not targeted for inspection. The uncertainty and complexity of onboard diagnostic systems would, in effect, work in the enforcement community's favor.

For this analysis, it was assumed that such monitoring would reduce by 10 percent the number of crashes in which vehicle-related defects of safety systems were cited as the critical reason. This is a conservative estimate, since in many instances major vehicle defects that directly lead to crashes should identifiable through fault code information, with the vehicle being taken promptly out of service. For example, if a vehicle had a major failure of the ABS, that would be detected through self-diagnostics and reported to the local enforcement agency as soon as the vehicle passed an inspection point. The vehicle would not be permitted to operate very long before it was targeted for detailed inspection and removed from service.

Further, there would clearly be some reduction in the number and/or severity of crashes where the critical reason for the crash was driver error, but where vehicle defects were nevertheless a contributing factor. The report's analysis of safety benefits did not take this into account.

4.4.2 Safety Benefits: Alternative 2—Vehicle Enhanced

Under this alternative, more detailed performance monitoring and reporting of brake, tire, and lighting system performance would be included as part of the message set, along with the same type of fault code information described in Alternative 1.

An analysis of roadside inspection data supported the LTCCS and showed that there is an important link between vehicle defects and crashes. Table 24 shows the result of roadside inspections for all inspections completed in the U.S. in 2004 (3 million inspections in total), as well as for a subset of these inspections completed on commercial vehicles that were actually involved in crashes (a total of 16,500 such inspections). The post-accident inspection data was screened to eliminate any violations that might have resulted from the accident itself (such as broken lights, load securement problems, etc.).

Table 24 shows that the number of OOS violations issued per inspection was three times as high for trucks involved in crashes as for trucks in general. Further, as a percentage of total inspections completed, brake-related OOS violations represented about 11 percent for all trucks, but about 30 percent for trucks involved in crashes. Tire-related problems (OOS violations) were also about three to four times more likely to occur on trucks involved in crashes as on trucks in general. Of interest is the fact that lighting-system OOS violations rates were similar between the two sample populations (all inspections versus post-accident inspections), and the LTCCS also showed that there were essentially no crashes in which the critical reason was given as a failed lighting system.

Available diagnostic technologies and methods for monitoring brakes and tires are quite comprehensive and, when combined with basic fault code information, they would likely be able to detect a majority of significant vehicle defects. Proceeding from this assumption, and recognizing that each commercial vehicle would probably be wirelessly inspected on almost every trip made, it would be highly unusual for a CMV to operate on the public roadways for any significant length of time without being detected by the local enforcement agency and appropriate actions being taken, including issuance of warnings, violations, and fines, as well as targeting the vehicle for more detailed Level 1 inspections. In the long run, it is likely that OOS violations related to brakes, tires, and lighting systems would be dramatically reduced (in much the same way that overweight violations have been dramatically reduced because of the high level of inspections and enforcement activity). It could be argued that once all vehicles were equipped with the type of technology envisioned by this alternative, crashes that have traditionally been directly caused by brake, tire, and lighting problems would be significantly reduced. For this analysis, and to take a conservative approach, it was assumed that 50 percent of all cases in which brake, tire, and/or lighting system failures were the critical reason for a crash would be eliminated.

4.4.3 Safety Benefits: Alternative 3—Driver Basic

Under this alternative, the operator's CDL number and electronic HOS log would be included in the SDMS. Because of the very high frequency of wireless inspections to be completed, fleets and operators would be highly motivated to fully abide by all HOS rules. It can be argued that abuse or disregard of HOS rules would be nearly eliminated, since violators would know they would be instantly caught. (It should be recognized that tampering and message falsification issues will no doubt exist, but should have little overall impact—particularly if severe enforcement actions are in place for operators caught tampering with the wireless inspection systems.) Compliance levels would, in the long run, probably approach 95—100 percent as the nation's fleets transitioned to wireless inspection technology.

To calculate safety benefits, the relationship of HOS violations to fatigue—and ultimately to crashes—must be established. The post-accident inspection data shown in Table 24 again provides some insight. Specifically, the analysis showed that OOS logbook violations are about twice as likely to be present for drivers involved in crashes as for the commercial vehicle driver population in general.

Table 24. Commercial Vehicle Roadside Inspection Violations—CY 2004
[All Inspections (ALL-Insp) = 3 million; Post-Accident Inspections (PA-Insp) = 16,500]

INSPECTION VIOLATION CATEGORY DESCRIPTION	ALL-Insp: Count of OOS	ALL-Insp: All Violations divided by Total Insp	ALL-Insp: OOS Violations divided by Total Insp	PA-Insp: Count of OOS	PA-Insp: All Violations divided by Total Insp	PA-Insp: OOS Violations divided by Total Insp
Medical Certificate	484	5.90%	0.02%	12	7.93%	0.07%
False Log Book	25,464	1.30%	0.8%	408	3.28%	2.47%
General Log Violations	70,536	9.40%	2.35%	702	13.15%	4.25%
10/15 Hours	56,081	5.40%	1.87%	391	6.86%	2.37%
60/70/80 Hours	9,572	0.30%	0.32%	46	0.30%	0.28%
All Other Hours-of-Service	1,912	6.00%	0.06%	14	7.11%	0.08%
All HOS Related	163,565	22.00%	5.50%	1,561	31.00%	9.50%
Disqualified Drivers	11,409	0.40%	0.38%	154	0.96%	0.93%
Drugs	2,000	0.10%	0.07%	63	0.40%	0.38%
Alcohol	3,979	0.10%	0.13%	164	1.06%	0.99%
Seat Belt	43	1.60%	0.00%		1.56%	0.00%
Traffic Enforcement	8	0.10%	0.00%		0.22%	0.00%
Radar Detectors	6	0.40%	0.00%		0.40%	0.00%
All Other Driver Violations	57,085	21.70%	1.90%	701	42.80%	4.25%
Brakes Out of Adjustment	96,307	9.60%	3.21%	1,764	31.75%	10.69%
Brakes, all others	229,124	25.40%	7.64%	3,196	41.22%	19.37%
Coupling Devices	8,058	0.60%	0.27%	230	2.08%	1.39%
Fuel Systems	9,361	0.90%	0.31%	247	2.14%	1.50%
Frames	13,911	1.50%	0.46%	323	4.02%	1.96%
Lighting	156,735	46.50%	5.22%	1,061	52.38%	6.43%
Steering Mechanism	10,610	1.70%	0.35%	256	2.65%	1.55%
Suspension	39,595	3.10%	1.32%	1,014	8.90%	6.15%
Tires	83,108	12.70%	2.77%	1,624	26.67%	9.84%
Wheels, Studs, Clamps, etc.	13,315	1.70%	0.44%	354	4.43%	2.15%
Load Securement	114,509	5.60%	3.82%	1,105	9.70%	6.70%
Windshield	406	4.00%	0.01%	21	5.32%	0.13%
Exhaust Discharge	1,866	3.00%	0.06%	35	2.93%	0.21%
Emergency Equipment	175	9.60%	0.01%		10.20%	0.00%
Periodic Inspection	230	6.00%	0.01%	2	8.39%	0.01%
All Other Vehicle Defects	64,695	23.60%	2.16%	1,303	37.05%	7.90%
Misc. Moving Violations, Others and Unknown	21,458	18.93%	0.72%	170	16.00%	1.03
Totals	1,102,042		36.70%	15,360		97.10%

While this information indicates a direct link between fatigue, HOS violations, and crashes, the most detailed study on this relationship was undertaken as part of the *Regulatory Impact Analysis for HOS Options*, completed in December 2002 by ICF Consulting and Jack Faucett Associates (the RIA HOS Study). This study compared the safety and economic impacts of alternative HOS regulatory options with the current HOS regulations, assuming 100-percent compliance and with current levels of non-compliance. A high-level summary of the findings of this study is shown in Table 25. The only things shown are data on the current HOS regulations with and without 100-percent compliance, as well as FMCSA's new HOS rules, since the other regulatory options examined in the study are not relevant here.

Table 25. Damages Attributable to Fatigue[5]

Long- and Short-Haul Categories	FMCSA New HOS Rules (100% Compliance)	"Old" Rule (100% Compliance)	"Old" Rule, Status Quo
% of Long-Haul Crashes Attributable to Fatigue	7.1%	8.5%	11.2%
Total Damages of Fatigue-related Long-Haul Crashes	$1,138	$1,361M	$1,791M
% of Short-Haul Crashes Attributable to Fatigue	3.7%	3.8%	3.9%
Total Damages of Fatigue-related Short-Haul Crashes	$492	$506M	$528M

The RIA HOS Study suggested that 100-percent compliance with HOS rules will have little impact on short-haul operations (defined as 150 miles or less in that study), but will have a major impact on long-haul operations. It should be noted that the percentage of crashes attributed to fatigue in this study were referenced to all commercial vehicle crashes, not just crashes for which the truck was assigned the critical reason. Table 24 indicates that fatigue-related crashes would be reduced from 11.2 percent to 8.5 percent with 100-percent compliance; this is roughly a 24-percent decrease in fatigue-related accidents.[*]

If the percentage reduction in crashes due to 100-percent compliance with HOS reported in the RIA Study (i.e., 24 percent) were to be applied to those crashes identified in the LTCCS as being linked to fatigue, then crash rates associated with fatigue would be reduced from 22 percent to 17 percent (again, only for those crashes for which the truck entity was linked to the critical reason). No credit is taken for reducing crashes or injuries for those crashes in which the other vehicle was assigned the critical reason, even though some percentage of commercial vehicle drivers in these accidents were also fatigued, and therefore full compliance with HOS regulations would likely have led to at least some small decrease in the number or severity of these crashes. For purposes of calculating crash reductions, it was assumed that a wireless inspection alternative as

[5] Federal Motor Carrier Safety Administration Regulatory Impact Analysis for Hours of Service Options, Prepared by ICF Consulting, Inc. and Jack Faucett Associates; Washington D.C.: 2002.

[*] 11.2 percent minus 8.5 percent, divided by 11.2 percent

described for Alternative 3 would lead to nearly 100-percent compliance with HOS rules. This would, in turn, lead to a 24-percent reduction in fatigue-related crashes.

It can also be argued that for other crashes which cited commercial vehicle driver error as the critical reason, there would also be some percentage reduction in crashes above and beyond those linked directly to fatigue. In other words, a wireless inspection program that routinely collected CDL credentials and HOS logbook data would yield additional indirect benefits related to improved driver hiring, screening, and training practices. For example, instances of disqualified drivers becoming involved in crashes would be reduced, since an operator that did not have a valid and current CDL would be quickly identified and cited. Over time, such drivers would simply not get behind the wheel, since they would know that they would be quickly identified and fined. For purposes of calculating potential savings, it is conservatively estimated that possibly 3 percent of the crashes caused by driver error (but not directly by driver fatigue) would be eliminated by a wireless inspection program of the type implied by Alternative 3. This percentage roughly corresponds to the percentage of commercial drivers involved in fatal crashes who were operating without valid CDLs. The inspection concept described would arguably reduce to nearly zero the percentage of drivers operating without a proper license.

4.4.4 Safety Benefits: Alternative 4—Driver Enhanced

Under this alternative, in addition to including CDL and HOS data in the message set (as in Alternative 3), direct operator performance measurement data would also be included using technologies such LDWS, eyelid-closure monitoring, and/or steering wheel sensors to measure alertness. Research conducted for this study did not uncover any individual fleet studies or case histories, even anecdotally, that credited such systems with a quantitative reduction in accidents. However, as noted in the discussion of Alternative 2, fatigue appears to be a significant contributing factor in 22 percent of all crashes in which the truck was linked to the critical reason for the crash. If full compliance with HOS regulations (which provide only an indirect link to fatigue) can achieve a 24-percent reduction in such crashes, it is reasonable that directly measuring fatigue (using LDWS and/or other drowsy-driver systems) could perhaps achieve a 50- percent reduction in crashes from the level of crashes that occur with full compliance with HOS regulations alone. Further, it is reasonable to assume that driver-monitoring systems would also reduce crashes that are related to driver error, but not directly linked to fatigue. For purposes of this analysis, it was assumed that such driver-monitoring systems would reduce those crashes associated with driver error (but not directly related to fatigue) by an additional 3 percent, beyond the 3-percent reduction noted under Alternative 3. It should be noted that while these percentage estimates are speculative, the end result in terms of reduction in number of crashes and fatalities is similar to the estimates contained in FMCSA's Draft Report for the MACK Field Operation Test (FOT), which included the use of LDWS. This study reported a reduction of between 90 and 140 fatalities for a nationwide deployment of LDWS. This is similar to the incremental increase in fatality reduction between Alternative 3 ("driver basic") and Alternative 4 ("driver enhanced").

4.4.5 Safety Benefits: Alternative 5—"Vehicle and Driver Basic"

Under this alternative, the SDMS would consist of basic fault code data as described in Alternative 1, and the CDL and electronic HOS logs as described in Alternative 3. In a practical sense, this would probably be the case if Alternative 3 were implemented. That is, if a wireless inspection program were implemented that focused on electronically and wirelessly extracting HOS logs, it would be simple to add existing fault code information to the message set, since such data is already available on the high-speed databus of commercial vehicles. This alternative then would yield the combined safety benefits of Alternatives 1 and 3.

4.4.6 Safety Benefits: Alternative 6—"Vehicle and Driver Enhanced"

Under this alternative, the SDMS would consist of the following: vehicle fault code data; performance monitoring of brake, tire, and lighting systems; CDL and HOS electronic logs; and direct measurement of driver fatigue indicators. This alternative represents the combined SDMS from Alternatives 2 and 4, and would yield roughly the combined safety benefits of both alternatives.

4.4.7 Safety Benefits: Baseline/Non-Cooperative Alternative

Estimating safety benefits from using advanced non-cooperative technologies to improve the current inspection process is troublesome. It is anticipated that by improving pre-screening of vehicles, there would most likely be some reduction in the incidence of crashes in which one of the inspected components is the cause. However, the major limitation of a non-cooperative approach is that there would be virtually no additional, real-time information collected about the driver. From a practical perspective, advanced non-cooperative vehicle inspection technologies can target only selected vehicle defect areas—specifically, brakes, major suspension problems, and lights using advanced sensor systems. Such vehicle defects account for perhaps 3–4 percent of commercial vehicle crashes. Thus, this concept would not target the principal cause of crashes, i.e. drivers.

4.5 OVERALL EVALUATION AND SELECTION OF SDMS ALTERNATIVES

Selection of the optimum wireless inspection concept is based on an evaluation of:

- A cost-benefit comparison
- Comparison of real-world institutional and deployment challenges

The first step to selecting the optimal SDMS alternative is to compare the expected safety benefits of each alternative (assuming a fully implemented inspection network) with the combined costs to establish the inspection infrastructure and to phase in the onboard units on all new Class III–VII commercial vehicles.

4.5.1 Monetizing Safety Benefits

The annual savings (in terms of reduced fatalities, injuries, and property damage) is used to estimate the monetary safety benefits for each of the wireless inspection alternatives. A summary of the estimated percentage reduction in crashes linked to various Critical Reason categories for each of the wireless inspection alternatives is presented in Table 26.

To calculate safety benefits, the percentage reduction estimates are applied only to that portion of total CMV crashes which would be impacted as discussed in the previous sections. For example, under Concept 5 ("vehicle and driver basic"), a 24-percent reduction in CMV crashes related to fatigue is estimated. However, according to the LTCCS study, only 64 percent of all CMV crashes are linked to the truck entity, and in only 22 percent of those crashes were the commercial vehicle drivers officially found to have been fatigued. In other words, commercial driver fatigue was a significant factor in 14 percent of all CMV crashes (22 percent × 64 percent), based on estimates from the LTCCS. Therefore, the estimate of a 24-percent reduction in fatigue-related crashes is applied to the 14 percent of all CMV crashes that are linked to fatigue, resulting in a reduction of about 3.4 percent in the total number of CMV crashes. Similarly, the 50-percent reduction in crashes directly linked to poor brakes (under Concept 2, "vehicle enhanced"), results in only a 1.3-percent reduction in total CMV crashes since poor brake performance is cited as the critical reason for the crash in only 2.6 percent of all CMV crashes.

Table 26. Estimated Percent Reduction in CMV Crashes for Each SMDS Alternative Concept

Critical Reason for Crash	As a % of all crashes where the Truck was assigned the critical reason for the crash	As a % of Total CMV Crashes	1 Vehicle Basic	2 Vehicle Enhanced	3 Driver Basic	4 Driver Enhanced	5 Vehicle and Driver Basic	6 Vehicle and Driver Enhanced
Driver Error:								
Fatigue	22%	14.1%	0%	0%	24%	36%	24%	36%
Misc. Driver	65%	41.6%	0%	0%	3%	6%	3%	6%
Total Driver	*87%*	*55.7%*						
Vehicle Defects:								
Brakes	4%	2.6%	10%	50%	0%	0%	10%	50%
Tires	2%	1.3%	10%	50%	0%	0%	10%	50%
Load Securement	3%	1.9%	0%	0%	0%	0%	0%	0%
Misc. Vehicle	1%	0.6%	10%	10%	0%	0%	10%	10%
Total Vehicle	*10%*	*6.4%*						
Total Other (environmental or unknown)	3%	1.9%	0%	0%	0%	0%	0%	0%
TOTAL	100%	64%						

Table 27 shows crash data from FMCSA Large Truck Crash Facts Study (2003), along with the average cost per event from the FMCSA's Cost of Crashes Study (2002). As shown in Table 27, CMV crashes cost the nation about $32 billion annually in monetary terms, and cause about 4,000 to 5,000 fatalities annually.

Table 27. Breakdown of Accidents Involving Commercial Vehicles[6] (CY 2002)

	# of Crashes	Cost per Crash	Total ($M)	Persons
Fatal Crashes	4,289	$3,800,000	$16,298	4,986
Injury-Only Crashes	84,000	$95,000	$7,980	122,000
PDO Crashes	347,000	$24,000	$8,328	0
Total	435,289	74,907	$32,606	

Table 28 shows the estimated reduction in fatalities as a result of implementing each SDMS alternative.

Table 28. Estimated Fatality Reduction Rate by SDMS (in crashes attributed to a commercial vehicle)

Critical Reason for Crash	% of Total Crashes	Fatal Crashes Associated with Critical Reason	1 Vehicle Basic	2 Vehicle Enhanced	3 Driver Basic	4 Driver Enhanced	5 Vehicle and Driver Basic	6 Vehicle and Driver Enhanced
Driver Error:								
Fatigue	22%	604	0	0	145	217	145	217
Misc. Driver	65%	1784	0	0	54	107	54	107
Vehicle Defects:								
Brakes	4%	110	11	55	0	0	11	55
Tires	2%	55	5	27	0	0	5	27
Load Securement	3%	82	0	0	0	0	0	0
Misc. Vehicle	1%	27	3	3	0	0	3	3
TOTAL FATAL CRASHES REDUCED			19	85	198	324	218	410
TOTAL FATALITIES SAVED			22	99	231	377	253	476

Fatality reduction is estimated by first calculating the number of fatalities associated with each critical reason for crashes, based on the associated percentage of total CMV accidents. This number was multiplied by the estimated percentage reduction from Table 28 shows that SDMS Alternative 6 has the highest fatality reduction rate, at 476 lives annually, while SDMS Alternative 1 has the lowest fatality reduction rate, at 22 lives annually.

A similar analysis was conducted for injuries as well as “property damage only” (PDO) accidents.

[6] Pacific Institute for Research and Evaluation, Revised Cost of Large Truck- and Bus-Involved Crashes, Final Report for Federal Motor Carrier Safety Administration, Washington, DC: 2002.

Table 29 shows the estimated injury reduction rate for each SDMS alternative, while Table 30 shows reductions in PDO crashes.

Table 28, Table 29, and Table 30 are multiplied by the data from Table 27 for the average cost of a fatality, injury, and PDO accident, and then summed to arrive at total cost savings (or benefits) for each SDMS alternative. This data is shown in Table 31.

Table 29. Estimated Injury-Reduction Rate by SDMS (in crashes attributed to a commercial vehicle)

Critical Reason for Crash	% of Total Crashes	Injury-Only Crashes Associated with Critical Reason	1 Vehicle Basic	2 Vehicle Enhanced	3 Driver Basic	4 Driver Enhanced	5 Vehicle and Driver Basic	6 Vehicle and Driver Enhanced
Driver Error:								
Fatigue	22%	11,827	–	–	2,839	4,258	2,839	4,258
Misc. Driver	65%	34,944	–	–	1,048	2,097	1,048	2,097
Vehicle Defects:								
Brakes	4%	2,150	215	1,075	–	–	215	1,075
Tires	2%	1,075	108	538	–	–	108	538
Load Securement	3%	1,613	–	–	–	–	–	–
Misc. Vehicle	1%	538	54	54	–	–	54	54
TOTAL INJURY ONLY CRASHES REDUCED			376	1,667	3,887	6,354	4,263	8,021
TOTAL INJURIES AVOIDED			547	2,420	5,645	9,229	6,192	11,650

Table 30. Estimated Property-Damage-Only Crash Reduction Rate by SDMS (in crashes attributed to a commercial vehicle)

Critical Reason for Crash	% of Total Crashes	PDO Crashes Associated with Critical Reason	1 Vehicle Basic	2 Vehicle Enhanced	3 Driver Basic	4 Driver Enhanced	5 Vehicle and Driver Basic	6 Vehicle and Driver Enhanced
Driver Error:								
Fatigue	22%	48,858	–	–	11,726	17,589	11,726	17,589
Misc. Driver	65%	144,352	–	–	4,331	8,661	4,331	8,661
Vehicle Defects:								
Brakes	4%	8,883	888	4,442	–	–	888	4,442
Tires	2%	4,442	444	2,221	–	–	444	2,221
Load Securement	3%	6,662	–	–	–	–	–	–
Misc. Vehicle	1%	2,221	222	222	–	–	222	222
TOTAL PDO CRASHES REDUCED			1,555	6,884	16,056	26,250	17,611	33,134

Table 31 shows that for SDMS Alternative 1, the estimated total benefits would be approximately $146 million annually. For Alternative 6, they would be $3.1 billion annually.

Table 31. Total Estimated Safety-Related Benefit by SDMS (in crashes attributed to a commercial vehicle)

Critical Reason for Crash	% of Total Crashes	Total $M Associated with Critical Reason	1 Vehicle Basic	2 Vehicle Enhanced	3 Driver Basic	4 Driver Enhanced	5 Vehicle and Driver Basic	6 Vehicle and Driver Enhanced
Driver Error:								
Fatigue	22%	$4,591	$0	$0	$1,102	$1,653	$1,102	$1,653
Misc. Driver	65%	$13,564	$0	$0	$407	$814	$407	$814
Vehicle Defects:								
Brakes	4%	$835	$83	$417	$0	$0	$83	$417
Tires	2%	$417	$42	$209	$0	$0	$42	$209
Cargo Securement	3%	$626	$0	$0	$0	$0	$0	$0
Misc. Vehicle	1%	$209	$21	$21	$0	$0	$21	$21
TOTAL ANNUAL BENEFITS ($MM)			$146	$647	$1,509	$2,467	$1,655	$3,114

4.5.2 Total Cost Estimates for Each Alternative and Benefit-Cost Analysis

To estimate the total annualized costs for each alternative, the inspection facility, equipment, and IT-related costs from Table 14 were combined with vehicle-related modification costs from Table 21 to calculate the total annualized costs. To simplify the analysis, infrastructure costs were amortized linearly over 10 years. This is probably a conservative assumption, since the facility modifications will actually last much longer than 10 years. Also, while a present-value analysis could be performed, the reality is that a wireless inspection infrastructure will probably be built out over several years in a manner that more or less matches the increased market penetration of new vehicles equipped with wireless inspection technology. To this extent, the one-time capital cost investment is actually an annualized investment, thus making a present-value analysis less appropriate.

Annualized incremental vehicle costs are based on the FY 2003 annual production estimate of 420,000 commercial vehicles (Class III–VII) from the American Trucking Trends 2004. Table 32 details the total annualized cost analysis for each alternative, and lists the safety benefits and the resulting cost-benefit ratio.

Note: It is important to understand that the monetized safety benefits presented are total societal benefits and not direct benefits to fleets. For example, the cost of a single fatal crash is estimated at about $3.8 million and includes the monetized "Quality-Adjusted Life Years" or QALY value. These costs are based on the present value of all costs over the victims' expected lifespan, including lost productivity, lost earnings, and the monetized value of the loss of quality of life that impacts a family because of the death of a family member. Further, the total costs presented *in the analysis are not total costs to a fleet, but total costs to society. For example, all costs associated with the infrastructure are included. These are not costs that would be incurred by fleets. The overall methodology (based on societal cost-benefits) is the same approach taken by FMCSA in its Regulatory Impact Analysis for the revised HOS rule.*

Table 32. Cost-Benefit Analysis by SDMS
(in Crashes Attributed to a Commercial Vehicle)

Critical Reason for Crash	1 Vehicle Basic	2 Vehicle Enhanced	3 Driver Basic	4 Driver Enhanced	5 Vehicle and Driver Basic	6 Vehicle and Driver Enhanced
Annual Benefits:						
Annual Fatalities Saved	22	99	231	377	253	476
Annual Injuries Saved	547	2,420	5,645	9,229	6,192	11,650
Total Annual Benefits ($MM)	*$146*	*$647*	*$1,509*	*$2,467*	*$1,655*	*$3,114*
Annual Costs ($MM):						
Amortized Facility & Equipment Infrastructure Cost (10 yrs)	$10.6–$17.6	$10.6–$17.6	$10.6–$17.6	$10.6–$17.6	$10.6–$17.6	$10.6–$17.6
Facility & Equipment Infrastructure O & M Costs	$9.4–$15.2	$9.4–$15.2	$9.4–$15.2	$9.4–$15.2	$9.4–$15.2	$9.4–$15.2
Amortized IT and Communication System Capital Costs (10 yrs)	$11.0–$16.5	$11.0–$16.5	$11.0–$16.5	$11.0–$16.5	$11.0–$16.5	$11.0–$16.5
IT and Communication System Operating Costs	$13.5–$27.0	$13.5–$27.0	$13.5–$27.0	$13.5–$27.0	$13.5–$27.0	$13.5–$27.0
Annual Incremental Vehicle Costs (based on 420,000 units/yr)	$100–$204	$579–$1,814	$197–$368	$661–$1,296	$224–$395	$1,589–$2,770$
Total Annualized Cost	$144–$280	$623–$1,891	$241–$444	$705–$1,372	$268–$471	$1,633–$2,846
Benefit/Cost Ratio						
High–Low	1.01– 0.52	1.04–0.34	6.26–3.40	3.50–1.80	6.17–3.51	1.91–1.09
Average	0.77	0.69	4.83	2.65	4.84	1.50

The results of the analysis in Table 32show that Alternative 1 has the lowest overall cost-benefit ratio at 0.77, while Alternative 5 (“vehicle and driver basic”) would likely yield the best cost-benefit ratio at 4.84, meaning the annualized benefits exceed annualized costs by a margin of almost 5 to 1. In other words, on an annual basis, the total costs for Alternative 5 would be repaid from savings due to reduction in crashes in about 2.5 months. Alternative 3, “driver basic”, offers nearly the same cost-benefit ratio as Alternative 5 (“vehicle and driver basic”), since most of the safety benefits are in fact derived from increased HOS compliance and monitoring of the driver.

4.5.3 Summary Comparison

Table 32 summarizes results of the overall comparison of SDMS wireless concept alternatives. Alternatives 1 and 2 offer only marginal improvements in safety in absolute terms, and their cost-benefit ratios are poor. On an absolute basis, Alternatives 4 and 6 offer the greatest safety benefits, with reductions in fatalities of 377 and 476, respectively. However, the implementation costs and institutional issues associated with widespread deployment make these alternatives unfeasible for near-term deployment. Both of these alternatives would require extraordinary research programs to develop technical standards and violation criteria for direct monitoring of vehicles and drivers.

Alternative 3 ("driver basic") offers significant safety benefits, and the implementation costs are reasonable. However, from a practical perspective, if a vehicle were equipped with the capability to wirelessly transmit the driver data implied by Alternative 3, then it would be technically quite simple also to include readily available vehicle fault data, (i.e., implementation costs for Alternatives 3 and 5 are nearly identical)—and not to do so, according to the findings in this Report, would be a wasted opportunity.

Alternative 5 ("vehicle and driver basic") does not rely on any new technology for deployment and would require only the installation of an appropriately designed data recording system, along with the wireless communications hardware (radio) and operating system. Additionally, no new standards need to be developed, nor does any consensus need to be reached on new vehicle safety systems or driver performance measurement methodologies. This alternative would leverage the increased diagnostic information already available on today's state-of-the-art heavy-duty trucks. It would enhance the ability to reap the benefits of the increasing sophistication in automated diagnostics that will inevitably occur over time. This alternative would also leverage the standardization work that is being considered as part of the EOBR effort—specifically, standards surrounding the format and extraction of electronic HOS logs.

Additionally, deployment of Alternative 5 provides a very good technical, timing, and programmatic fit with other industry efforts. Specifically, it complements efforts by the Joint Program Office to develop standard vehicle-to-infrastructure communications and efforts by the EPA to develop standard emission-related fault codes to monitor compliance with new stringent emission regulations that will go into effect near the end of this decade (i.e., heavy-duty OBD II standards).

Based on overall cost effectiveness and ease of implementation, SDMS Alternative 5 is the recommended alternative for moving forward into Task 5, and the alternative for which business and technical deployment plans are detailed.

Table 33. Overall Comparison of Wireless Inspection SDMS Alternatives—by Criteria
(Favorability Ratings: 4 = Very Favorable, 0 = Very Unfavorable)

SDMS Alternatives	Key Output Data	Costs	Effectiveness in Reducing Crashes	Institutional Issues/Challenges	Other Development Challenges
1. Vehicle-Basic	Readily available fault code information related to brakes, transmission, engine and electrical system. Also VIN number. Favorability:	4	Likely minor impact. Fault code data is not a direct measure of safety system performance, and vehicle defects not strongly linked with crash rates. 0	Vehicle data likely considered less "private" than driver information. 3	Wireless vehicle diagnostics already being offered by OEMs. May be able to directly leverage OBDII technical approach. 3
2. Vehicle-Enhanced	As above, but include specialized diagnostic data for brakes, tires, and lighting systems failures. Favorability:	2	Little to moderate impact. Brakes, tires and lighting defects loosely linked with crash rates. 1	Vehicle data likely considered less "private" than driver information, but lack of consensus around "failures" will be a challenge. 2	Substantial research program needed to develop violation criteria based on safety system sensor measurements. 1
3. Driver-Basic	Electronic HOS Record, CDL #, and VIN Favorability:	3	Likely very effective, would dramatically reduce HOS violations. 2	Likely push back from industry due to privacy and cost concerns. Similar to current NPRM for EOBRs only more intense due to ease with which HOS data could be extracted. 2	Development of a cost effective reliable means of positively identifying driver to vehicle is a challenge programs like TWIC and REAL ID would need to be leveraged. 2
4. Driver-Enhanced	Same as 3, but also Driver "performance" information—specifically LDW data. Other drowsy driver monitoring systems can be added. Favorability:	1	Significantly more effective than 3 since direct measurements of driver performance would be added. 3	Likely strong push back due to privacy and cost concerns, and technical validity of measurements. 0	Substantial research program needed to develop violation criteria based on safety system sensor measurements. 1
5. Vehicle- and Driver–Basic	1 and 3 Combined Favorability:	3	Combined safety benefits of concepts 1 and 3. 2	Similar to 3, but with some added concerns with collection of vehicle data. 2	Similar to 3 but with added complexity of developing new violation criteria based on fault code information. 2
6. Vehicle- and Driver-Enhanced	2 and 4 Combined Favorability:	0	Major Safety Benefits. Comprehensive monitoring of driver and vehicle crash causation factors. 4	Substantial privacy, cost, and technical validity concerns. 0	Substantial research program needed to develop violation criteria for both driver and vehicle monitoring. 0

5.0 DEPLOYMENT PLANNING

5.1 RATIONALE FOR CONTINUED RESEARCH

A fundamental question to be answered before moving forward with developing strategies for implementing the wireless inspection concept is:

Considering FMCSA's role as an enforcement agency, should FMCSA move forward with research in wireless inspection concepts?

Based on the cost-benefit ratios calculated in Task 4, the Research Team's interviews with a variety of industry stakeholders, feedback from the public RFI process, and the important changes occurring in the commercial trucking industry, the answer would appear to be a clear "YES." The rationale for pursuing research related to the wireless inspection concept is summarized as follows:

- **Overwhelmingly positive benefit-cost ratio**. The analysis presented in this Report showed that the total costs for implementing a wireless inspection concept (both the public-sector infrastructure costs and the private-sector incremental vehicle costs) could be recouped in well under 1 year, based on savings from reductions in fatalities and injuries.
- **No new technology is required**. While there are certainly technical challenges related to functional requirements, standards, and IT support systems that must be addressed, the fundamental technology for collecting the onboard data and transmitting it wirelessly is already available.
- **The concept would support real-time identification of CMV operators**. Several recent studies, including the Large Truck Crash Causation Study and ATA's Driver Risk Study, have confirmed that:
  - Driver error is the leading cause of CMV crashes
  - Drivers with poor safety records are more likely than other drivers to be involved in future crashes
  - Drivers with improper or disqualified credentials are involved in a disproportionate number of fatalities

Therefore, real-time identification of the CMV driver could be leveraged to improve vehicle screening, identify disqualified drivers, and discourage such drivers from operating a CMV to begin with. Coincidentally, programs such as TWIC and REAL ID are developing requirements and standards for electronically identifying the driver using smart-card technology. FMCSA does not have to develop this capability, and these programs could be leveraged to help spur changes in CDL standards to permit drivers to electronically identify themselves to the truck.

- **The selected concept does not call for collecting any information which is not already collected by FMCSA.** Alternative 5 ("vehicle-plus-driver basic") would wirelessly collect basic vehicle fault code data along with HOS logs, VIN, USDOT number, and CDL number. All of this information is already collected by CMV enforcement agencies during roadside inspections. Legal and policy issues associated with collecting the data should therefore be minimized.

- **The concept augments FMCSA's ongoing efforts related to EOBRs.** FMCSA is developing standards for the electronic reporting (or file format) for HOS data. This work could be directly leveraged to support inclusion of this information in a wireless SDMS.
- **The concept would support the needs of other Federal Agencies**. EPA is currently engaged in rulemaking which calls for emission inspections on in-service heavy-duty vehicles in the 2010 timeframe using electronic onboard diagnostic (OBD) technology. EPA (and CARB) is already engaged in developing an emissions data message set which is conceptually identical in form to an SDMS. However, from an implementation perspective, EPA has not yet finalized how, where, and when such emission inspections will take place. Preliminary conversations with EPA indicate that they are very interested in exploring with FMCSA the possibility of leveraging the roadside safety inspection program as a venue for completing emission inspections as well. Conceivably, EPA and FMCSA could jointly explore a means for wirelessly extracting both safety- and emissions- related diagnostic data.
- **Implementation costs are likely to come down, while available onboard safety information will increase.** As noted above, advances in heavy-duty vehicle design continue to emphasize more capability for self-diagnostics, while the cost of such technology is dropping. Electronic braking systems, collision warning devices, and other driver-monitoring systems continue to increase their market penetration. As these technologies become more commonplace, information from these systems might be downloaded to augment various screening and enforcement strategies (for example, strategies targeted only at carriers with very poor safety records).
- **The wireless inspection concept supports CSA 2010 Goals.** Goals of FMCSA's Comprehensive Safety Analysis 2010 effort include:
  - Increased emphasis on driver accountability
  - Leveling the playing field through uniform application of compliance and enforcement procedures
  - Improving the agency's high-risk motor carrier identification systems

Clearly, all of these goals would be supported by a wireless inspection program. Driver accountability is increased through real-time identification of the driver and verification of proper credentials. The playing field is leveled for two reasons: First, the inspection net would be widened to include more trucks operating in multiple environments; and second, the frequency of wireless inspections would be linked to miles traveled (activity levels) rather than predetermined inspection algorithms, the size or history of the carrier, and/or human judgment by enforcement officers. Finally, the ability to identify high-risk motor carriers would be greatly improved because of much greater overall inspection frequency and collection of safety data on all vehicles.

- **The current CVISN and COMPASS efforts provide an ideal platform for rolling out the wireless inspection concept**. As noted earlier, current State and Federal CMV information and communication systems will need to be modified and expanded to take full advantage of CMV wireless inspection capability. CVISN is already poised to develop standards associated with electronic screening as well as methods for sharing such data between States. These efforts will help in standardizing the specific hardware and software needed at inspection stations in order to support wireless data download and analysis capability, thus gaining economies-of-scale. At the same time, the COMPASS effort is updating FMCSA's entire suite of customer interface, data analysis, and data warehousing applications. It would be an opportune time for making provisions in these new applications to accommodate the expanded data to be gathered through wireless inspections.

5.2 CHALLENGES FOR DEPLOYMENT

While overall, the wireless inspection concept offers tremendous potential for improving the safety and efficiency of motor vehicle operations, there remain very significant challenges for widespread deployment:

- **Costs to fleets.** As with many such initiatives, even though there is a predicted net benefit for the industry and public overall, many fleets would not experience a positive return on investment because of their already-good safety record. These fleets would view the concept only in terms of increased costs. Many of the more sophisticated fleets already have the capability for wireless communications through a satellite or cellular telematics service provider, and would view it as redundant and/or wasteful to require them to add short-range communications capabilities. (Many of the fleets that participate in electronic screening programs or electronic toll collection already have dedicated short-range communications via their onboard RFID tags.) Most fleets will see the added costs to participate in a wireless inspection program as just that—added costs with no direct benefit. Although the benefits are long term and are based on reduced crashes, the prevailing attitude of fleet managers will be, "Why do I want to spend money on something that will make it easier for enforcement agencies to issue violations?"
- **Privacy and misuse of data.** An additional major concern among fleets relates to whether and how information collected could be misused. Two broad areas of concern exist: 1) Data collected by the State could be subpoenaed by trial lawyers for use against the trucking company whose vehicle was involved in an accident (this is discussed in the institutional issues section); and 2) Vehicle location and other competitive data might somehow become publicly available or otherwise be acquired by competitors through unlawful means.

These cost and data privacy concerns on the part of fleets, as well as a general aversion to having their vehicles monitored "unnecessarily," strongly suggests that fleets will not freely adopt such technology on their own, especially since current electronic screening programs already allow fleets to bypass stations by downloading only the carrier identifier information.

5.3 ALTERNATIVE DEPLOYMENT STRATEGIES

With this background there are two broad strategies for moving forward with deployment of the wireless inspection program:

1. **Leverage USDOT's current VII Initiative.** This approach would seek to establish a long-term, strategic relationship with the CMV industry to develop a standardized vehicle-to-infrastructure communications infrastructure and associated value-added safety and commercial application**s.** Specifically, this approach would call for FMCSA to

become more fully engaged in the Vehicle Infrastructure Integration (VII) effort now being sponsored by the Joint Program Office, and to partner with leading fleets and heavy-duty vehicle OEMs in developing a variety of market-driven safety and commercial applications that are supported by the 5.9 GHz standards. Such technology and applications would offer real and immediate value to fleets—and our preliminary discussions with truck OEMs indicate they are anxious to pursue the VII technology. Once the industry adopts the DSRC technology, then costs to introduce the wireless inspection concept would be greatly reduced. At that point, either a direct regulatory approach could be taken that would require downloading of safety data, or a "soft" regulatory approach could be considered in which FMCSA would leverage its influence with States so that they would modify electronic pre-clearance programs to require additional, real-time safety data to be downloaded before vehicles would be permitted to bypass inspection stations. In other words, if a truck did not wirelessly transmit an electronic SDMS, it would not be permitted to bypass the station and would almost certainly be targeted for a full Level 1 inspection. Since all new trucks would be equipped with the VII technology, fleets would be highly motivated to voluntarily download their SDMSs. The phase-in of such enhanced electronic pre-clearance programs would need to be carefully managed and matched to the market penetration of trucks equipped with the DSRC technology so that inspection stations would not be overloaded with manual inspections at one extreme, or underutilized at the other extreme. This is the approach recommended by the Research Team. It is a longer-term approach, but would clearly set FMCSA, and the industry, on a path toward major improvements in CMV safety and efficiency.

2. **A regulatory approach**. From a technical and cost-benefit perspective, there would appear to be sufficient justification for initiating a regulatory effort, particularly if a joint effort with the EPA were to be adopted. However, this approach is not recommended due to the political, policy and institutional obstacles that would have to be overcome.

Leverage USDOT's VII Initiative

Wireless inspections represent only one of many safety applications that could be made possible though standardized vehicle-to-vehicle and vehicle-to-infrastructure communications using the 5.9 GHz DSRC platform. As important, the DSRC medium allows for the development of numerous commercial and convenience applications that offer added value to commercial vehicle fleets, shippers, and vehicle OEMs. Therefore, the deployment of a wireless inspection program could coincide with a larger initiative to encourage the adoption of DSRC technology within the commercial-vehicle, heavy-duty sector. From FMCSA's perspective, wireless safety inspections may represent the premier application that is enabled by DSRC, but there are clearly many other safety and non-safety applications that will help build the business case for adoption of this standardized communications media by the industry.

Currently, USDOT is aggressively working in the light-duty sector to develop and deploy DSRC technology. Fortunately, much of the core wireless communications technology development has already been completed under that program, such as the allocation of spectrum by the FCC exclusively for transportation applications and the development of functional and performance standards for a DSRC radio. Under the light-duty DSRC program, an agreement has been established between USDOT and a consortium of light-duty vehicle manufacturers (known as the Vehicle Infrastructure Integration Consortium or VIIC) to jointly develop and deploy DSRC technology. The VIIC is focused on integrating the DSRC radio into a light-duty vehicle architecture and developing safety and non-safety applications targeted at light-duty motorists. Most of these applications are common to heavy-duty vehicles as well (e.g., traffic information advisories, intersection collision avoidance, financial transactions, electronic signage, and electronic brake lights).

However, the commercial motor vehicle industry will require unique applications, including:

- **Wireless safety inspections** (as described in this Report)
- **Dynamic emission inspections** (per EPA proposals)
- **Low-bridge warnings**: The infrastructure broadcasting the height of the bridge to approaching vehicles and messages sent by the truck that automatically warn the driver whether or not he/she has sufficient clearance
- **Lane departure warning assist**: The accuracy and efficiency of onboard LDWS can be enhanced by having the infrastructure broadcast precise lane geometry and road maps
- **Rollover warning assist**: Rollover and stability control systems can also be enhanced by having a roadside beacon broadcast details about road conditions, as well as curve geometry and inclination
- **Electronic signage for CMVs**: The infrastructure would broadcast information specific to the needs of CMVs, including the availability of commercial vehicle parking spaces at the next exit, availability and price of diesel fuel, and availability of various types of maintenance
- **Open-road tolling and electronic commerce**: DSRC technology permits the development of standardized, open-road tolling applications that would allow trucks (and automobiles) to bypass all toll plazas. It would allow the highway operator to develop highly tailored pricing structures based on vehicle type and roadway usage. The DSRC technology also provides electronic payment applications that would permit truckers to pay for various services (including fuel) in a more convenient and automated manner
- **Electronic Freight Manifest**. The DSRC technology and infrastructure will also support the secure downloading by multiple vehicles (at highway speeds) of complete onboard bills-of-lading and freight manifest data. Such capability could be leveraged at various intermodal transfer points to improve efficiency of load consignments and increase throughput
- **Numerous other safety and non-safety applications (**developed to leverage the standardized DSRC communication platform).

In addition to the above, the needs of other Federal agencies could be accommodated by the VII technology platform. For example, TSA is interested in more effectively tracking the movement of hazardous shipments, and U.S. Customs and Border Protection is interested in improving the efficiency of CMV crossings at the border through more advanced exchange of information. A standardized means of wirelessly transmitting information from the vehicle to the roadside is an important and necessary first step.

The DSRC infrastructure could be leveraged for private-sector, operationally-focused applications that allow for communications of trip, location, manifest, and other data. In other words, while considerable infrastructure network design and analysis will be required, it is likely that the DSRC infrastructure could be leveraged by fleets that currently do not subscribe to a long-distance telematic service provider to communicate with their vehicles.

The potential safety and non-safety benefits for the trucking industry from deploying DSRC would appear to be at least equal to those for the light-duty sector. Therefore, FMCSA could consider engaging the heavy-vehicle sector in a cooperative partnership arrangement to integrate DSRC radios into the heavy-vehicle architecture and to develop and demonstrate applications focused on the commercial motor vehicle sector. Such applications would eventually include wireless vehicle inspections. A consortium of truck manufacturers could be engaged to lead the technical development (much like the current light-duty VIIC), and fleets could be engaged to help lead development and demonstration of safety and non-safety applications. The highest-level objectives of the Commercial Vehicle Infrastructure Integration (CVII) program would be to:

- Address and resolve technical issues associated with DSRC integration into a heavy-duty vehicle platform
- Showcase important safety and non-safety applications unique to the commercial vehicle sector (including wireless vehicle inspections)
- Address and resolve privacy, security, and tampering concerns important to the commercial trucking and safety enforcement communities
- Identify need and opportunities for standardizing categories of message sets to support safety applications, emission inspections, security applications, and/or unique message sets for hazardous material shipments and others
- Provide additional insight into requirements for the IT and communications infrastructure needed to support the applications
- Provide additional insight into requirements for initial wireless access points (locations of roadside units) to serve the commercial vehicle industry.

Like the light-duty DSRC program, the overall goal of the CVII program would be to complete sufficient testing and demonstration so that all key commercial-sector stakeholders (including truck OEMs, fleets, States, and Federal agencies) have sufficient information to make a consensus decision regarding widespread deployment and adoption of the DSRC technology. For the light-duty program, this date falls in late 2008. A unique schedule and set of activities for the CMV VII program would need to be developed that paralleled, but did not overlap, the light-duty program.

This deployment strategy hinges on building an overall business case with the commercial vehicle sector to the effect that DSRC technology offers substantial benefits for improving safety, enhancing mobility, supporting security initiatives, and providing a standardized communications link to commercial vehicles that can be used by both the private and public sectors. To help encourage participation in an overall CVII program, FMCSA and the USDOT would need to enter into a public-private partnership with truck OEMs, fleets, and others, and support the program on a shared-cost basis. Preliminary discussions with a limited number of fleets and heavy-duty vehicle OEMs indicate a strong interest in working with USDOT on VII initiatives.