NTRCI

NATIONAL TRANSPORTATION RESEARCH CENTER, INCORPORATED
UNIVERSITY TRANPORTATION CENTER

Trusted Truck® II (Phase A)

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List of Abbreviations and Definitions

BMS	Volvo's Business Management System
CDL	Commercial Drivers License
DSRC	Dedicated Short Range Communications
EDGE	A technology used on GSM cellular networks that allows increased data transmission rates and improved data transmission reliability over and above GPRS
EOBR	Electronic On-Board Recording used to record hours of service for a truck driver
EVDO	Evolution Data Optimized. A digital cellular data service available to users of CDMA (Code Division Multiple Access) cellular networks. Although not compatible with GSM networks, EVDO supports data rates even higher than EDGE
GPRS	General Packet Radio Service, a cellular data service available to users of Global System for Mobile Communications (GSM)
GPS	Global Positioning System
GSM	Global System for Mobile communications
HMI	Human Machine Interface
NOK	Not OK - A negative condition or response (the opposite of "OK")
NTRCI	National Transportation Research Center, Inc.
OBC	On-Board Component - The hardware and software in the vehicle
TFT	Thin Film Transistor. A type of LCD (Liquid Crystal Display)
TTMC	Trusted Truck® Management Center which is part of the Road Side Companion that receives the inspection data from the OBC, responds to the vehicle with the inspection result, and if necessary, notifies the Bypass Notifier
US DOT	U.S. Department of Transportation
VIN	Vehicle Identification Number
VMT	Vehicle Miles Traveled
VTEC	Volvo Technology Corporation
VTEC-US	Volvo Technology Corporation-United States
WAAS	Wide Area Augmentation System, technology used to improve the accuracy of the GPS (Global Positioning System)
WIFI	Wireless Technology Standard, also called 802.11

EXECUTIVE SUMMARY

The Trusted Truck® Program was initiated in 2003 as a joint effort by NTRCI, Volvo and UT. The vision of the Trusted Truck® program is to develop a secure and "trusted" transport solution from pickup to delivery. The program's objective is to increase safety, security, and efficiency of truck transportation by presenting wireless credentials to roadside inspectors that confirm that the tractor, trailer and cargo meet all appropriate requirements for safe transportation of the cargo. By presenting these credentials without the need for the truck to stop, the number of inspections increase, the efficiency of the system improves, and inspectors can have more time to target trucks that are more likely to have safety and security violations. The Trusted Truck® II project is the four year continuation of this program.

A demonstration of the Trusted Truck® II Year 1 functionality was successfully performed on April 25th at Volvo US Headquarters in Greensboro, NC. A new Volvo Trusted Truck® was equipped with several off-the-shelf systems to detect brake lining & stroke, tire pressure & temperature as well as the pressure status of an in-cab fire extinguisher. In addition, the tractor could detect the status of the lighting and stability control as well as seatbelt systems. The trailer was also equipped with a brake system that reported the status of the trailer's brake stroke.

All the data generated from these systems was transferred to the roadside using a standard commercial cellular data link (GPRS). This year's effort also introduced the Trusted Truck® Management Center (TTMC), a data repository to be operated by a third party that consolidates all data as it is received from the truck and performs the wireless inspections. The TTMC is also capable of adding look-up data, demonstrated on April 25th by the addition of the make and model of the truck together with the name of the carrier and driver. The demonstration showed a "trusted" vehicle bypassing a roadside inspection using the TTMC as the method of delivering the inspection results electronically to the inspection station. It also demonstrated that if the vehicle failed the wireless inspection, the truck driver was informed on an in-dash display to enter the inspection station in the same manner as all other vehicles without Trusted Truck® status.

Three successful demonstration runs of the truck were made:

1. The truck had no faults and passes the wireless inspection. With the automatic setting at the TTMC enabled, the driver gets an in-cab prompt to bypass the inspection. The bypass notifier indicates to inspection station personnel that a "trusted" truck has been allowed to bypass the station.
2. The truck has a brake fault and does not pass the wireless inspection. The automatic response from the TTMC notifies the driver via an in-cab prompt to enter the inspection station. The bypass notifier does not indicate anything to the inspection station that could identify the truck, which enters the station as part of the general population of trucks on the highway.
3. The truck has a lighting fault and does not pass the wireless inspection. The automatic response is not enabled at the TTMC and the TTMC operator initiates a message to the truck, giving the driver the in-cab prompt to enter the inspection station. The bypass notifier does not indicate anything that could identify the truck, which enters the station as part of the general population of trucks on the highway.

Based on the successful demonstration of the Trusted Truck® II Year 1 work program, the Trusted Truck® team recommends moving forward to the second year of the program which will focus expanding the communications to the trailer and providing more real-time trailer safety information. Year 2 will also focus on developing the business model for Trusted Truck®, as well as defining the implementation scenario for future years.

CHAPTER 1. BACKGROUND

The U.S. Department of Transportation (US DOT) conducts close to 750,000 roadside inspections of commercial vehicles per year. Even with this seemingly large number of inspections the DOT is still being overwhelmed with the burden of performing inspections in a fashion that ensures that the carriers are complying with safety regulations without negative impact on the profitability of the carriers. In the first Trusted Truck® Project of 2003/4, Volvo helped demonstrate the ability to perform brake inspections wirelessly between the vehicle and the US DOT roadside infrastructure using 802.11a communications ("WIFI"). The current effort builds off of the experiences from this original project to further explore the concept of wireless roadside inspection. The goal of the first year's project was to move closer to defining a mechanism for performing wireless vehicle inspections. The project also has potential future relationships with other work being proposed at the University of Tennessee including truck safety at traffic signals, wireless sensors, and data encryption.

The library of previous work done in the area of wireless inspections is extensive. We have limited ourselves to four projects and programs with applications and technologies related to the Trusted Truck® program's past, present and planned future areas of application.

I-95 CORRIDOR COALITION WIRELESS INSPECTION & DRIVER ID DEMO

The effort successfully demonstrated the technical feasibility of utilizing 802.11b (Wi-Fi) to wirelessly communicate selected driver and vehicle data elements from a commercial motor vehicle (CMV) operating at highway speed to a stationary 'reader' located at the 'roadside.' The commercial vehicle in this case was a specially equipped Volvo truck test bed provided by Volvo Trucks North America. The data elements communicated from the vehicle to the roadside consisted of (a) driver information read from a simulated Transportation Worker's Identification Credential (TWIC) smartcard, (b) the results of an onboard process that attempted to 'match' a real time scan of the driver's fingerprint with an image of the fingerprint stored on the smart card, and (c) the real time status of the vehicle's brake system from information on the vehicle data bus.

The wireless capability was developed by personnel of Volvo Technology of America. The Commercial Vehicle Safety Alliance (CVSA) and the Institute for Transportation Research and Education of NC State University provided technical assistance and input to the system requirements definition process. CVSA and NCSU-ITRE also ensured 'linkage' between the present effort and ongoing government efforts at FHWA and FMCSA (e.g., FHWA's Vehicle Infrastructure Integration, exploratory investigations of wireless capabilities at FHWA, and FMCSA programs in CVISN and truck tracking).

Funding for the demonstration was provided by FMCSA through the Commercial Vehicle Operations Track of the I-95 Corridor Coalition. Volvo and the North Carolina State Highway Patrol (NCSHP) shared equally in the required 50/50 funding match.

The demonstration, which was conducted at the Volvo facility in Greensboro, North Carolina, was witnessed by motor carrier enforcement personnel from the North Carolina State Highway Patrol as well as the leadership of the Coalition CVO program track, representatives from industry, and representatives from FMCSA at both the state and federal level.

For purposes of the demonstration, the test vehicle drove repeated trials of a 7 mile ‘circuit’ around the Volvo plant. The geometry of the circuit permitted evaluation of the effective range of communication of the system (approximately 1 mile line of sight). Whenever the vehicle was within effective communication range the client (vehicle) system broadcast the data message set described above to the server (stationary or roadside) component of the system. Prototype in-vehicle displays indicated to the driver the results of the authentication process and whether the driver was permitted to bypass the stationary facility or was required to pull in for closer observation. Prototype displays were also generated for use at the roadside (stationary) facility. These displays permitted the roadside observer to view the location of the vehicle (as plotted on a map using GPS location data transmitted as part of the message set), the results of the driver authentication process, as well as the assessment of vehicle brake status.

At the outset of the project, an ‘enforcement workshop’ was held to introduce NCSHP and other motor carrier enforcement personnel to the general concepts and potential for conducting wireless ‘inspections.’ Those in attendance were prompted to consider the range of data elements and their perceived inspection value, the conditions under which they believed enforcement should be ‘alerted’ to anomalies; and the manner in which believed such an alert(s) should be provided. Based upon these initial inputs the project team developed an extensive on-line survey in an attempt to quantify the perceived importance of these data elements to (a) compliance, (b) safety, and (c) security. The survey was made available on-line to the enforcement membership of CVSA. The intent of the survey was to generate discussion within the enforcement community as to the context-dependent nature of the information conveyed by these data elements with respect to their ‘actionable’ value for compliance, safety, and security purposes.

The work accomplished here represents a small, but essential, component of a larger, system-level concept developed by the project team. That system level concept is described in the final report.(ITRE, 2006) (FMCSA, 2006)

<u>TRUSTED TRUCK® I</u>

Figure 1 (Photograph) Volvo Demonstration Truck

Trusted Truck® I was a demonstration of dedicated short-range communications that helps to maximize customer uptime by providing real-time truck brake data across a wireless, WIFI based, network. This allows the government inspection station to reduce time-intensive, manual brake inspection, and get data from the many trucks they do not have time to inspect.

A Volvo 660, long-haul truck was fitted with a Knorr-Bremse Electronically Controlled Brake System, a GPS receiver, and the Trusted Truck® hardware. The Trusted Truck® "ECU" provided a J1939 vehicle interface, the wireless interface and GPS interface. The inspection station was fitted with a custom server application that determines vehicle condition and automatically directs the vehicle to proceed or to stop.

When entering the network, the vehicle (client) broadcasts vehicle ID, overall status, and position. The server can request detailed brake data, including brake lining remaining, brake pressure, and relative wheel speed, and can also direct the vehicle to stop or proceed.

<u>Demonstration Truck and on-board Unit</u>

The Volvo truck used for the demonstration is shown in figure 1. Several separate systems provided the data used for the wireless transmission to the roadside, including a specially designed on-board unit shown in figure 2.

Figure 2 (Photograph) On-Board Unit

<u>Inspection Station Application</u>

Figure 3 (Screen Shot) Inspection Station Application

A special user interface was designed for the project and ran in an IBM compatible PC environment located in the inspection station. A picture of the user interface is shown in figure 3.

The user interface made it possible to request more detailed information from the truck, resulting in a detailed screen shown in figure 4.

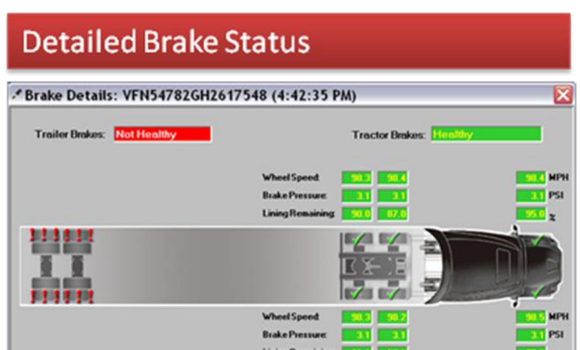

Figure 4 (Screen Shot) Detailed Brake Status

Project Poster

A separate poster was created and used to promote the Trusted Truck® Program. An image of the poster is shown in figure 5.

(Video: VTA, UTK, 2006)

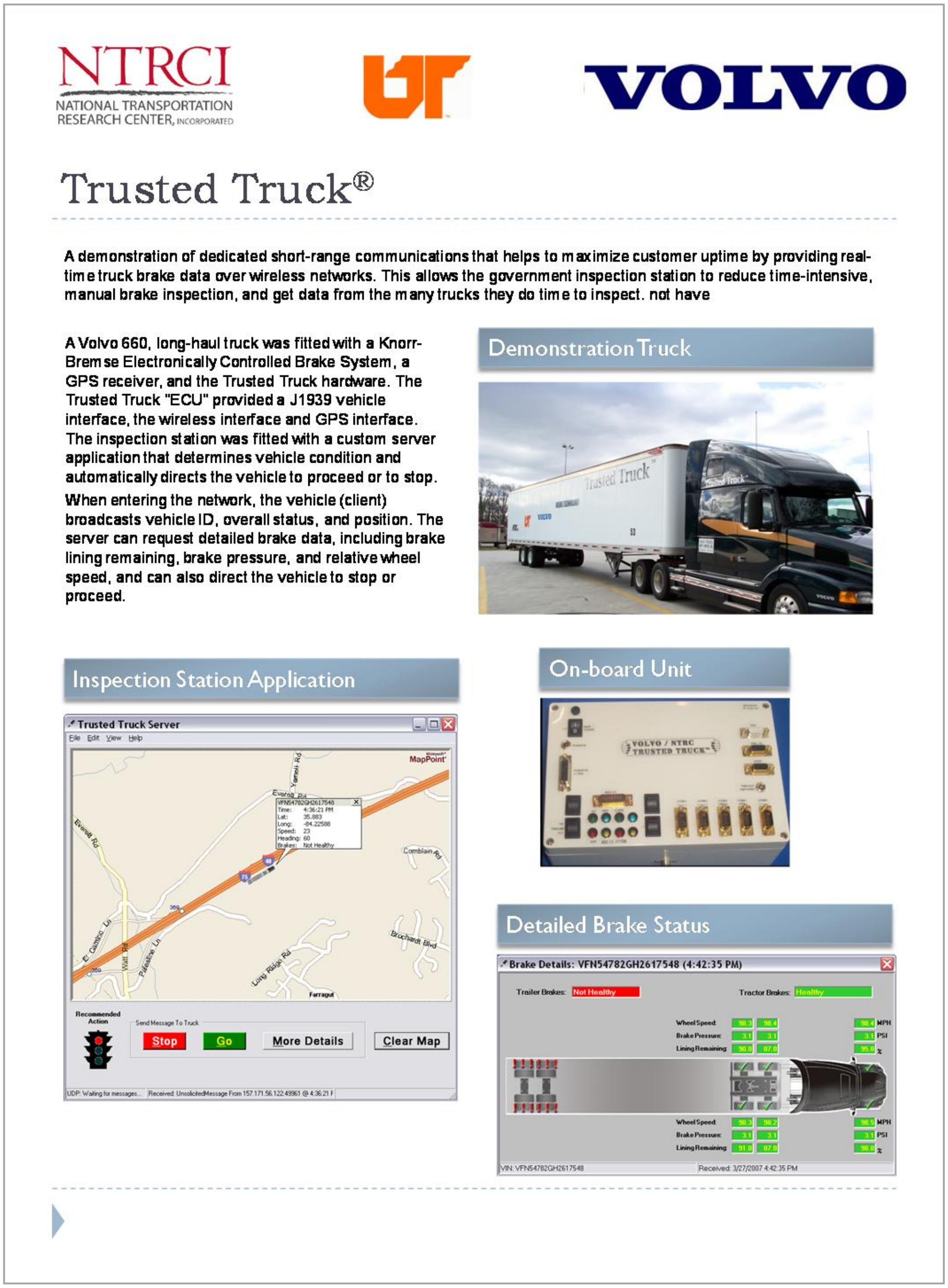

Figure 5 (Poster) Trusted Truck ®

FMCSA WIRELESS INSPECTION PROGRAM

The overall project goals are to develop alternative concepts to support commercial vehicle inspections; leverage advanced on-board sensor systems and vehicle communication technologies; and evaluate concepts relative to safety impacts; estimated cost of implementation; and institutional and policy issues.

Current inspection activities include three million roadside safety inspections each year taking approximately 45 minutes to an hour to complete. Currently approximately 1,200 fixed facility inspection stations and 1,000 portable/mobile units are available to conduct these inspections and result in a 73 percent violation rate, 23 percent vehicle out-of-service rate, and 7 percent driver out-of-service rate (OOS). The sheer volume and time investment as compared to projections in freight movement growth require a need for improved inspection processes. Many carriers experience infrequent inspections averaging less than one per year and many CMVs over 10,000 – 26,000 lbs are rarely inspected since most current inspection programs are directed at interstate carriers using tractor-trailers.

Opportunities for technology applications to assist in the effort include a focus on identification of items to be further inspected. Examination of CMV crash data can be completed to help identify items that should be inspected. Data show that most crashes 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 a significant portion of CMV crashes. Lastly, where a vehicle defect was the critical reason for the crash, brakes, tires and load securing issues were most often cited.

A Request for Information was issued and responses included such items as communication standards/protocols; data concerns; data message content and structure; end-user concerns; inspection frequency level; and implementation strategies.

A technology assessment indicated the most viable option for Wireless Inspection Concepts include Dedicated Short-Range Communication (DSRC) at 5.9 GHz. DSRC at this frequency is designed for vehicle-to-infrastructure communications, has high data rates up to 27 Mbps, and can support many other safety and productivity applications. Evaluation of the concepts of operation resulted in need for a data message set based on basic items such as driver license number and log book information and vehicle fault codes. A more enhanced system may include driver-fatigue warning systems, lane tracking systems, collision-avoidance systems, vehicle brake sensors, and tire pressure monitoring systems.

The anticipated benefits of these systems include a shift in the way inspections are handled currently; more frequented electronic safety checks; reduction in the number of unsafe CMV drivers and vehicles on the road; and reduction in crashes related to unsafe CMV drivers and vehicle defects.

Next steps include conduct of proof of concept field tests at the FMCSA Roadside Test Lab; development of data interchange and message set standards; partnering with states and motor carrier industry to resolve institutional issues; and coordination with ongoing testing and deployment programs.

Outline

- Project Description
- Need for Improved Inspection Processes
- Comments from Request for Information

- Technology Assessment
- Concept Evaluation
- Recommended Solution
- Estimated Costs and Benefits
- Next Steps

Project Description

Overall Project Goals

- Develop alternative concepts to support commercial vehicle inspections
- Improve the accuracy and efficiency
- Allow for increase in total number of inspections completed
- Leverage advanced on-board sensor systems and wireless communication technologies
- Evaluate concepts relative to:
    - Safety impacts
    - Estimated cost of implementation
    - Institutional and policy issues

Current Inspection Activities

- million roadside safety inspections each year
- 45 minutes to an hour to complete
- 1,200 fixed facility inspections stations
- 1,000 portable/mobile units
- 73% Violation rate
- 23% Vehicle Out-Of-Service rate
- 7% Driver OOS rate

Need For Improved Inspection Process

- Infrequent inspections
- Average less than one per year
- Many CMVs over 10,000 – 26,000 lbs rarely inspected due to operations
- Current inspection program directed at interstate carriers using tractor-trailers
- 27% of all CMV fatal crashes involve straight trucks
- 40% of all CMV crashes occur on secondary roads
- Inspection program challenged by both volatility and growth in the CMV sector
- 3.3% annual growth for number of CMVs and VMT
- 40,000 new entrants annually
- In last 20 years, 1 million new tractor-trailers on highways

Opportunities for Technology

Analysis of historical inspection data (table 1) reveals that a large portion of significant "defects" are limited to a few items

With the exception of load-securement, most of the key vehicle and operator condition criteria lend themselves to on-board electronic monitoring and diagnostic assessment.

Table 1. Analysis of Historical Inspection Data

Driver Violations	% Driver OOS Violations
Logbook	40.0%
HOS	28.7%
CDL	19.4%
Total	88.1%
Vehicle Violations	**% Vehicle OOS Violations**
Brakes	41.2%
Lighting	16.6%
Tires	9.4%
Load Securement	15.7%
Total	82.9%

Identification of Items to be Inspected

- Examination of CMV crash data also completed to help identify items that should be inspected
- Most crashes linked to driver error
- While "fatigue" is not directly cited as the "critical reason" for a crash, drivers were cited as being fatigued in a significant portion of CMV crashes
- Where a vehicle defect was the critical reason for the crash, brakes, tires and load securement issues were most often cited
- Critical Reasons in One Truck-One Passenger Vehicle Crashes (FMCSA Large Truck Crash Causation Study) (figure 6)

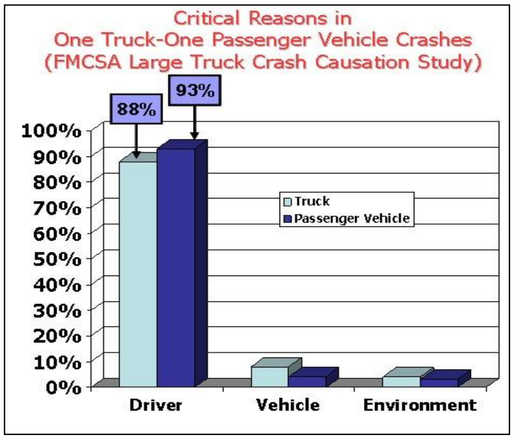

Figure 6 (Chart) FMCSA Large Truck Crash Causation Study

Comments From Request For Information

Request For Information Responses issued in September 2005: 27 respondents, including fleets, drivers, OEMS, safety advocacy groups, and the enforcement community (table 2)

Table 2. Request for Information Responses.

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/Individual	6
Total	27

RFI Responses

- Communication Standards/Protocols
- Data Concerns
- Security, integrity, privacy
- Data Message Content & Structure
- End-User Concerns
- Operator resistance, electronic falsification, O&M
- Inspection Frequency Level to Change Behavior
- Implementation Strategies to Equip Every CMV

Technology Assessment

- Most Viable Option for Wireless Inspection Concepts
- Dedicated Short-Range Communication (DSRC) at 5.9 GHz
- 5.9 GHz DSRC has significant advantages:
- Designed for vehicle-to-infrastructure communications and has high data rates up to 27 Mbps
- Can support many other safety and "convenience" applications

Concept Evaluation

- Deployment-based
- Fixed, mobile, virtual, remote, kiosk, etc.
- Data Message Set-based
- Basic
  - Driver – License number and log book information
  - Vehicle – Fault codes
- Enhanced
  - Driver – Fatigue warning, lane tracking, and collision-avoidance systems
  - Vehicle – Brake sensors, tire pressure monitoring

Recommended Solution

Driver and Vehicle Basic

- Driver Basic
  - Driver identification, CDL status, and log info

- Vehicle Basic
  - Fault codes

Wireless Inspection Concept Deployment Plan

- State and Federal Government
- 1,200 fixed facility inspection sites
- 1,000 virtual inspection stations
- 500 mobile inspection vehicles
- IT infrastructure (roadside to back office systems)
- Motor Carrier Industry
- All CMVs equipped with DSRC and on-board computers

Estimated Costs And Benefits

Costs

- Public sector annual costs of $45M – $76M
- Private sector annual costs of $224M – $395M
- $533 - $940/vehicle
- 420,000 new vehicles equipped per year

Benefits Assumptions

- Dramatic Paradigm Shift
- Electronic safety checks will be frequent and expected
- Number of unsafe CMV drivers and vehicles on road would be reduced
- Crashes related to unsafe CMV drivers and vehicle defects would be reduced
- Size & weight program comparison

Table 3. Violation Rate Comparison.

	CMV Size & Weight Program	CMV Safety Inspection Program
Number of Inspections	82 M	3 M
Violation Rate	0.63%	73%

Table 4. Benefit-Cost Analysis.

ANNUAL BENEFITS	
Annual Lives Saved	253
Annual Injuries Prevented	6,192
Total Annual Benefits ($)	$1.7B
ANNUALIZED COSTS	
Government-Facility, Equipment, IT, Communications Capital Costs (Amortized over 10 years)	$22M-$34M
Government-Facility, Equipment, IT, Communications O&M Costs	$23M-$42M
Industry-Annual Incremental CMV Costs (Based on 420,000 units/yr.) ($533 - $940/CMV)	$224M-$395M
Total Annualized Cost	$269M-$471M
BENEFIT/COST RATIO	
High – Low	6.17:1-3.51:1
Average	4.84:1

Next Steps

- Conduct proof of concept field tests
- Develop data interchange and message set standards
- Partner with states and motor carrier industry to resolve institutional issues
- Coordinate with ongoing testing and deployment programs (e.g., CVISN grants, I-95 Corridor Coalition efforts, Vehicle Infrastructure Integration program)
- Investigate broader DSRC applications for trucks and buses

CVISN SAFETY INFORMATION EXCHANGE FOR COMMERCIAL VEHICLES IN CONNECTICUT

For more than 10 years, the Connecticut DMV has been a leader in the development and deployment of safety information exchange technologies for roadside enforcement of motor carrier regulations. Connecticut DMV was the first in the U.S. to deploy a statewide wireless communication system that provides inspectors with real-time access to carrier safety information. Past inspection records, numerical safety ratings, out-of-service orders, vehicle registration information (via the National Law Enforcement Telecommunications System) and commercial driver license (CDL) information are now available wirelessly. In-state data for assessing a carrier's current operating credentials—including International Registration Plan (IRP) registrations, International Fuel Tax Agreement (IFTA) licenses, and oversize/overweight permits—are soon to be available on-line wirelessly (via the Commercial Vehicle Information Exchange Window, or CVIEW).

The DMV, working in concert with the state's Department of Public Safety and other agencies, is currently integrating this robust wireless system with the latest technologies for electronic screening and credentialing. Figure 7 shows one of the weigh and inspection stations in Connecticut that is applying many CVISN technologies for safety, efficiency, and enforcement.

Figure 7 (Photograph) Union Weigh/Inspection Station on I-84 in NE Connecticut

The CVISN program, under the direction of the Federal Motor Carrier Safety Administration (FMCSA) within the U.S. Department of Transportation (U.S. DOT), is part of Connecticut's statewide ITS deployment. In 1996, Connecticut became one of ten pilot/prototype states that began field operational testing of CVISN technologies. The goal of CVISN is to foster a national network of compatible technologies, achieved through a common architecture.

CVISN emphasizes three main deployment areas: credentials administration, electronic screening (weigh station bypass), and safety information exchange. Because of Connecticut's advanced approach to roadside enforcement, this case study is focused on safety information exchange capabilities as they relate to the overall CVISN deployment in Connecticut. Safety information exchange is the electronic exchange of current and historical safety data and supporting credential information regarding commercial carriers, vehicles, and drivers.

The main objective of the safety information exchange deployment in Connecticut is to enable state DMV Commercial Vehicle Safety Division (CVSD) and Department of Public Safety commercial vehicle (CV) inspectors to concentrate their efforts on those motor carriers with poor or unknown safety records, while allowing the trucks of safer, known carriers to continue safely down the road. Throughout the process, Connecticut has sought to establish and maintain an integrated statewide safety and credentials data exchange network that can be linked with regional and national data sources.

The most significant accomplishment to date has been the statewide deployment of 68 specially equipped laptop computers, known as mobile data terminals (MDTs), one of which is shown in figure 8. The MDTs give inspectors access to updated information on a motor carrier's safety, out-of-service, license, and credential records, as well as information on specific commercial vehicles and drivers. The vehicle based MDTs—and comparable equipment in the state's fixed-site weigh stations—make the inspectors' jobs more efficient.

Figure 8 (Photograph) CVSD Inspector using MDT to run a wireless query on a Hazardous Cargo Carrier

As Connecticut enters a new phase of CVISN deployment, the state is enhancing its roadside enforcement program through the integration of electronic screening and electronic credentialing capabilities. This integration will give the inspectors a fuller, more timely and usable picture of the motor carriers and commercial vehicles traveling the highways of the state.

The deployment of safety information exchange in Connecticut has been funded in part through a cost-sharing partnership agreement with the U.S. DOT's ITS Joint Program Office (JPO). FMCSA manages the CVISN program with support from the JPO.(FHWA/FMCSA, 2004)

CHAPTER 2. PROJECT TEAM

Under the program direction of NTRCI, The University of Tennessee, Volvo Truck North America, and Volvo Technology of America have been collaborating for over four years on the Trusted Truck® Concept. These efforts wish to further their successful demonstration of the capability of a Class 8 truck to wirelessly send vehicle status information from the truck to the Inspection Station at highway speeds. The four year project will enhance the concept through investigating the integration of technologies such as adding more vehicle data, driver's license data, data from the trailer, cargo data and finally biometric verification of the driver's identity to the inspectors as well as data validation, secured and encrypted data transmission and tamper proofing technology.

For the first year of this four-year effort the project partners demonstrated their commitment to the continuation of the Trusted Truck® Project by cost sharing well in excess of the required 20%.

CHAPTER 3. VISION

Year 1 of this four-year effort was focused on the tasks involved in preparing the vehicle for an automatic initial and remote inspection performed while the vehicle is in motion. The purpose was to enable a "trusted" vehicle to bypass a true roadside inspection providing the initial automated inspection produced "trusted" data indicating it did not warrant further investigation. The vision of the Trusted

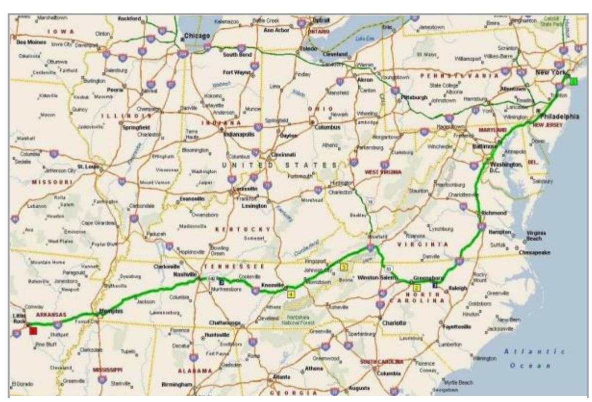

Figure 9 (Map) Sample Trusted Truck® Route

Truck® program is to develop a secure and "trusted" transport solution from pickup to delivery across our nation as shown in figure 9.

This program is a road map to safer, more secure and efficient transportation. A key part of the Program's goal is to provide solutions that generate help to both the commercial trucking industry as well as to the enforcement community. This will help ensure a wider acceptance and a quicker and smoother deployment of the system.

CHAPTER 4. OVERVIEW

In Year 1 the project defined a set of vehicle and driver data that is useful to roadside inspectors performing safety inspections remotely. The project also defined a useful mechanism for presenting this data to the roadside inspection team for evaluation. In addition the project investigated the ability to validate this data and provide a quick go/no-go decision.

Year 1 introduces the Trusted Truck® Management Center (TTMC), a third party repository of inspection and other vehicle data. The data included on-board data such as vehicle and driver identification which was passed to the TTMC for use in determining whether a vehicle can bypass the inspection station or not. A second application called the bypass notifier, running in the inspection station, allows the station to view any "trusted" trucks that have been granted bypass status by the TTMC. The various options to a truck in the Trusted Truck® Program are shown in figure 10.

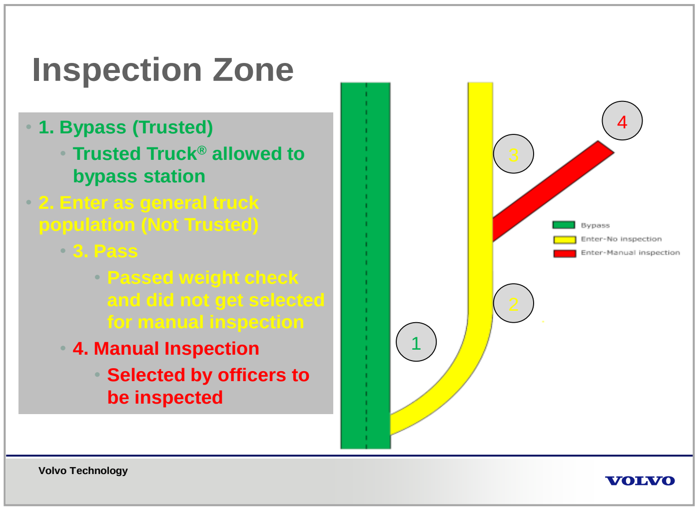

Figure 10 (Diagram) Inspection Zone

In order to stay "neutral" between the enforcement and industry communities, the Trusted Truck® Program is limiting the information provided by the bypass notifier in the inspection station. In addition, it does not provide any notification or information to the station about trucks that fail a wireless inspection by the TTMC. Instead, these trucks are directed to enter the station just like any other truck in the general population that is not part of the Trusted Truck® Program. This approach ensures an incentive for participants in the program to invest in the several on-board systems required to provide the inspection data set, without risking unfair selection by inspectors should any of these systems fail.

SYSTEM DESCRIPTION

The system is designed to facilitate a "wireless inspection" of a commercial vehicle as it approaches an inspection station. The communication of inspection data takes place in zones. The current project has defined the approaching and the inspection zones. A future loading zone concept is prepared with the purpose to set up the entire transport with all communication zones along the way.

A graphical representation of the communication zones is shown in figure 11.

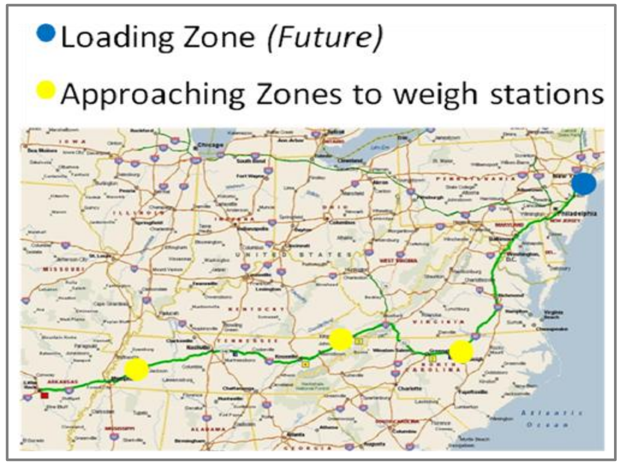

Figure 11 (Map) Communication Zones

Each approaching zone precedes an inspection zone as shown in figure 12.

Figure 12 (Map) Approaching Zone and Inspection Zone

The concept encompasses vehicle data that can provide a profile of the vehicle that determines whether it is "trusted" enough to bypass the station or otherwise must enter the inspection station along with the general population (i.e. all other non-"Trusted Trucks").

CHAPTER 5. SYSTEM DESIGN

The system contains three parts, the On-Board Component (OBC), the Trusted Truck® Management Center (TTMC) and the Bypass Notifier. The On-Board Component resides in the vehicle, the TTMC resides at a (potentially) off-site location, and the Bypass Notifier resides at the inspection station. The OBC and the TTMC are communicating via a wireless communication link, while the TTMC and the Bypass Notifier use a wired link.

A descriptive graphical overview of the system is provided in figure 13.

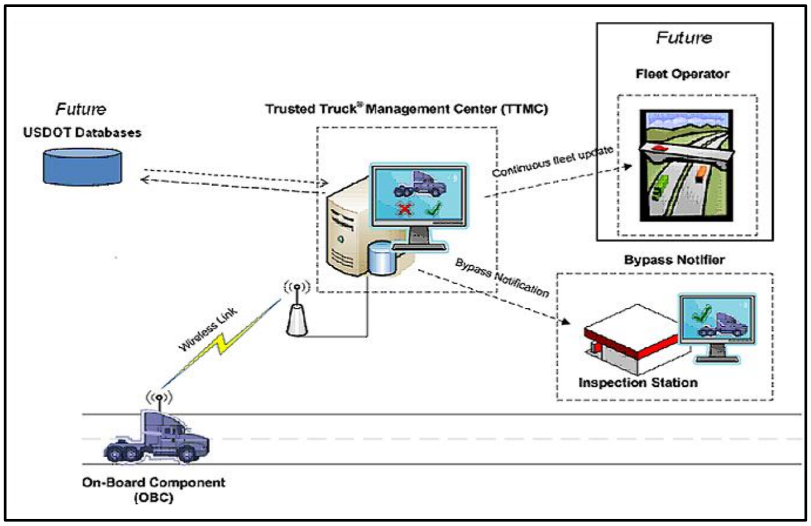

Figure 13 (Diagram) System Design Overview

The TTMC displays the inspection data, received from the OBC, to the system user and allows the user to respond with the approval or disapproval for bypassing the inspection station. The Bypass Notifier, when triggered by the TTMC, will provide notification to the inspection station's personnel when a “trusted” vehicle is cleared to bypass the inspection station. Additionally, the TTMC is designed to support possible future functions that could enable historical records for each vehicle to establish "trust" in the vehicle and/or carrier with regard to inspections, leading to an incentive for vehicle operators to keep their vehicles' safety and maintenance standards high. As a further benefit, a future function of the TTMC can provide vehicle operators with notification of failed wireless inspections. This will assist vehicle operators in keeping their vehicles' safety and maintenance standards high.

On approaching the inspection station, the OBC collects inspection data from the vehicle's electronic systems and transfers the inspection data to the TTMC. The OBC also provides a notification to the vehicle driver regarding the approval or disapproval of bypassing the inspection station (i.e. the result of the wireless inspection), as received from the TTMC. If the vehicle must enter the inspection station, the inspection station personnel are not notified of the failed wireless inspection and the vehicle is treated no differently than the general population (i.e. all other non-"Trusted Trucks").

The wireless link is an ongoing work in progress throughout the multiyear Trusted Truck® program. The initial project used WIFI, 802.11a, and currently we are using a cellular data connection (GPRS or EDGE). In the future years we may evaluate other VII compliant communication technologies such as Dedicated Short Range Communications (DSRC).

The OBC and TTMC shall communicate wirelessly via GSM according to the following diagram in figure 14.

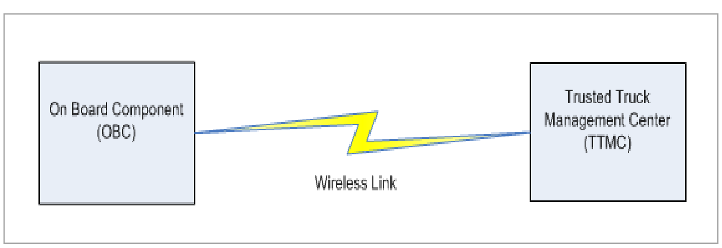

Figure 14 (Diagram) Graphical Representation of Wireless Link

INSPECTION DATA SET

The following data is currently provided by the OBC to the TTMC:

- **VIN:** Vehicle Identification Number.
- **DOT#:** Department of Transportation number (Identification of commercial carrier).
- **IFTA#:** International Fuel Tax Association number.
- **License Tag:** The State and license Plate # was stored on board the vehicle and sent to the TTMC.
- **Driver's License:** The driver uses a PIN code to log into the on-board system. The PIN code is used to retrieve the CDL# and simulated name of the driver. The name and other personal information could potentially be collected from an external data base such as the USDOT's along with other information such as criminal records etc.
- **Make and model of truck:** This could also potentially be collected from an external data base using the VIN#.
- **Seatbelt usage:** Checked via a sensor installed for the driver's seat belt
- **Brake status:** The status of the tractor's and trailers' brake systems, including the status of the brake stroke (slack adjusters) as well as the status of the tractor's brake lining
- **Tire inflation:** Including tire pressure and temperature
- **Stability System:** The status of Volvo's proprietary stability system.
- **Lighting System:** The status of Volvo's proprietary lighting system
- **Fire Extinguisher:** An aftermarket monitoring system was installed to collect presence and pressure status of an in-cab fire extinguisher

VISIT TO THE GREENE COUNTY INSPECTION STATION

On October 16th 2007 the project team visited the Greene County Inspection Station outside of Knoxville, Tennessee. Oak Ridge National Laboratories (ORNL) demonstrated several systems including:

- A brake inspection system designed to quickly and accurately inspect each individual brake without the driver leaving the cab. The system uses a pit that also allows additional inspection points. The system can simulate axle weight by clamping and pulling down the trailer.
- A wireless inspection system using DSRC technology and simulated data displayed on a user interface in the inspection station

An infrared inspection system detecting overheating by brakes or wheel bearings
None of the systems can be used for enforcement at this point, but certainly as screening tools.

The station officers also displayed several systems that they used to keep the highways safe and secure:

- ASPEN: a computerized system that automates several steps in the inspection process and generates the inspection reports

A federal database to check CDL history and driver's background checks
As subsequent years of the project will most likely perform demonstrations at this location the project team also successfully verified the coverage of the possible data networks GPRS, EDGE and EVDO as well as located equipment such as a flat screen TV and a 10Mbps internet connection (currently without firewall).

The officers and staff at the inspection station also offered direct input into the inspection data that is most useful to them. Their input significantly helped forge the list of inspection data and the general functionality of the Trusted Truck® System, helping the project team make minor adjustments to, and finalize the requirements.

SYSTEM REQUIREMENTS

A detailed specification list was created as the first deliverable for the project. It was created in cooperation with UT and NTRCI and approved by NTRCI before any significant software development was started. It includes the identification of all the data elements needed and the inspection criteria for a go or no-go message to the vehicle, based on previous work done on wireless inspections as well as on the input and feedback from operators at the Greene County inspection station.

This document describes the NTRCI Trusted Truck® II system requirements and is organized by the requirements housed in Caliber RM requirements management tool.

SENDING OF INSPECTION DATA

When the vehicle approaches the inspection station, the OBC shall send vehicle and driver data to the TTMC. The approach distance at which this action is triggered shall be determined through testing in order to give ample time for the TTMC to analyze the received inspection data and respond to the vehicle, potentially allowing the vehicle to bypass the inspection station.

Vehicle Data

The OBC shall provide the following vehicle-related information to the TTMC:

- Vehicle Identification Numbers (VIN) for the tractor and up to two trailers
- US Department of Transportation number (US DOT#)
- License plate number and issuing state abbreviation for the tractor and up to two trailers
- International Fuel Tax Agreement (IFTA) number
- Identifying description of the tractor (color, type [daycab or sleeper] and make [Volvo])
- Identifying description of the trailer(s) (type, color if applicable)
- Tractor tire pressure and temperature
- Tractor lighting OK/NOK
- Fire extinguisher presence and operational OK/NOK
- Tractor Anti-lock Braking System OK/NOK
- Tractor brake system condition as reported by MGM's eStroke system

Driver Data

The OBC shall provide the following driver-related information to the TTMC:

- Commercial Driver's License number (CDL#)
- Current seat belt usage

Programmable Data

The following data shall be programmable without modifying the software in the OBC:

- Vehicle Identification Numbers (VIN) for up to two trailers
- US Department of Transportation Number (US DOT#)
- International Fuel Tax Agreement (IFTA) number
- License plate number and issuing state abbreviation for the tractor and up to two trailers
- Identifying description of the tractor (color, type [daycab or sleeper] and make [Volvo])
- Identifying description of the trailer(s) (type, color if applicable)
- Commercial Driver's License number (CDL#)

INSPECTION DATA RESPONSE

The TTMC shall provide approval or disapproval for bypassing the inspection station to the OBC after receiving the OBC's vehicle and driver data, giving the driver ample time to enter or bypass the inspection station. The TTMC's response may be generated manually by the user, or automatically by the TTMC.

Automatic Inspection Response Criteria

When the TTMC is configured to automatically generate inspection responses, the TTMC shall use the following criteria to determine if the vehicle is approved to bypass the inspection station.

At the instance the "wireless inspection" is performed, the vehicle shall not have:

- One of more tires with a pressure condition reported as "extreme over pressure" or "extreme under pressure" by the vehicle's tire pressure monitoring system.
    - The following conditions are allowed for any number of tires: "over pressure", "under pressure", "error indicator" and "not available".
- One or more brake assemblies reported as "non-functioning", "overstroke", or "dragging brake".
    - The following condition is allowed for any number of brake assemblies: "sensor error".
- One or more brake assemblies reported as having "0% lining remaining".
    - The following condition is allowed for any number of brake assemblies: "10% lining remaining".

Note: The fire extinguisher presence and operational status, tractor ABS status, and driver seal belt usage data items are not part of the automatic inspection criteria.

DRIVER NOTIFICATION

The OBC shall notify the driver of the TTMC's approval or disapproval for bypassing the inspection station.

Notification Dismissal

The OBC HMI shall automatically dismiss the bypass approval/disapproval notification when the vehicle has passed by or exited the inspection station.

INSPECTION STATION DATA DISPLAY

The TTMC shall display the inspection data provided by a new vehicle approaching the inspection station.

Lookup of Additional Information

The TTMC shall combine the inspection data received from the vehicle with additional, static (hard-coded) information as retrieved from a data store. The relationship between the received inspection data and the additional information is provided in table 5.

Table 5. Relationship between the Received Inspection Data and the Additional Information

Driver's CDL#	First and Last Name
	Criminal Record
	Outstanding Warrants (if any)
	Residential Address
	DMV Photograph
Tractor's USDOT#	Carrier's Name
	Carrier's Contact Information
	List of Carrier's Known Logos
	List of Past Violations (if any)
Tractor's VIN	Make
	Model
	Year
	Type/Style
	Primary and Secondary (if applicable) Colors
	Last Known Odometer Reading
	List of Past Inspections

BYPASS APPROVAL NOTIFICATION

The TTMC shall trigger the Bypass Notifier to notify the inspection station's personnel when a "Trusted Truck" has been allowed to bypass the inspection station. The notification allows the bypassing truck to be positively identified and prevents needless interception by law enforcement personnel.

Bypass Disapproval Concealment

The TTMC shall not provide a notification to the inspection station's personnel when a vehicle is not approved to bypass the inspection station (i.e. fails the wireless inspection). The "untrusted" vehicle is not to be flagged or examined any differently than a vehicle of the general population.

CHAPTER 6. IMPLEMENTATION

The implementation started with the identification of the equipment needed to implement and test the system. The project team identified and procured all hardware and software tools and systems needed to complete the functionality of the system.

From the onset it became clear that we would have to alternate between vehicles as the project progressed to ensure speedy verification and testing of the various systems in the trucks while still procuring a vehicle with all the needed alterations and systems appropriate for the final demonstration.

During the course of the project the project team installed all the supporting systems in the trucks and trailer as well as all the stationary roadside equipment. For logistical purposes it was decided late in the project to place the demonstration at Volvo's HQ in Greensboro, North Carolina, instead of Knoxville, Tennessee. It is however likely that the future years of the project will conduct demonstrations at the Greene County inspection station outside of Knoxville, Tennessee. Furthermore the team created a virtual setup of all pertinent equipment used for the project in a lab test environment capable of simulating the actual operation of the vehicle inspection.

Software development of all modules in the system commenced, including the development of the TTMC and the bypass notifier. A mapping application was also used for the demonstration to show the real time whereabouts of the truck during the various demonstration runs.

TTMC

The TTMC is the biggest of the applications developed for the project. It communicates with the truck through a commercially available cellular data link (GPRS). It also communicates with the bypass notifier using a communication protocol that operates on the Internet. To enhance the real time experience at the demonstration, a mapping application was used to display the real time GPS location of the truck at all times.

The user interface of the TTMC includes several fields using the data received from the truck as well as look-up data such as name of driver. It also displays the data sets received from trucks entering the approaching zone. Each "pass" into the zone is recorded separately and displayed in the left pane.

When the TTMC is not in automatic mode, the "bypass" or "enter" message to the truck can be generated manually using two buttons.

The TTMC screen can show one of three tabs:

- "**General**": showing the general safety information with status of the fire extinguisher, seatbelt, stability and lighting systems.
- "**Brakes**": showing brake lining and stroke of the tractor and stroke of the trailer
- "**Tires**": The pressure and temperature of each of the tractors tires

For quick reference the various system statuses are shown in three colors:

- **Green**: indicates that all systems are reporting and status is OK. This state will result in a passed inspection.
- **Yellow**: indicates a minor error such as a sensor not reporting or a value is approaching an unsafe level. This state will result in a passed inspection.
- **Red**: indicates that a value is unsafe or a system is failing. This state will result in a failed inspection.

A screen shot of the TTMC's screen with the "general" tab is shown in figure 15 with all general systems OK.

Figure 15 (Screen Shot) TTMC screen "General" tab

A screen shot of the TTMC's screen with the "brakes" tab is shown in figure 16. In this screen the tractor's brake lining is reporting an unsafe value

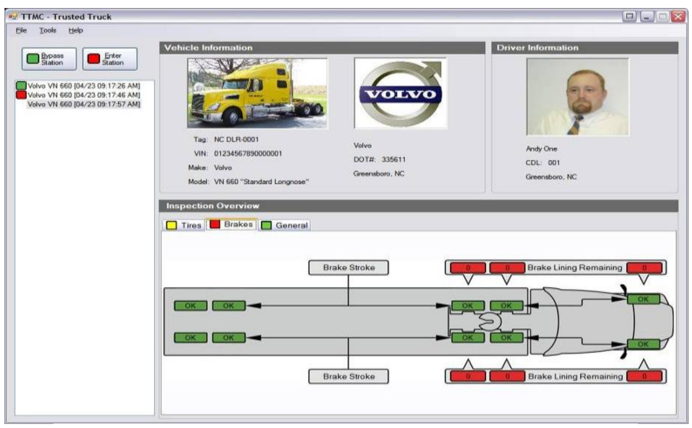

Figure 16 (Screen Shot) TTMC screen "Brakes" tab

A screen shot of the TTMC's screen with the "tires" tab is shown in figure 17 with all systems OK.

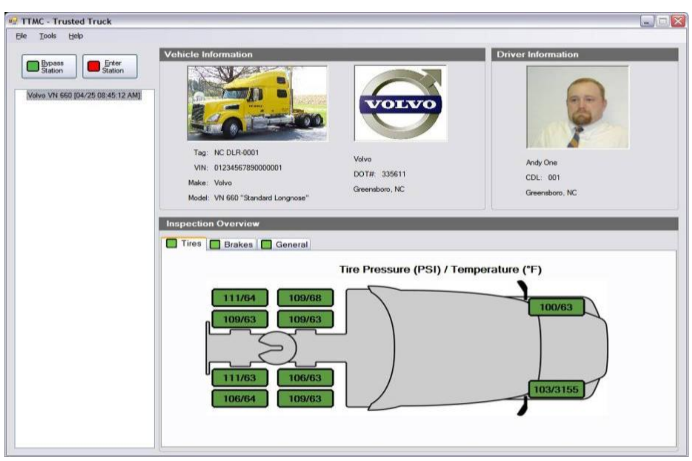

Figure 17 (Screen Shot) TTMC screen "Tires" tab

BYPASS NOTIFIER

The bypass notifier is developed to display limited data to the inspection station for each "trusted" truck that has passed a wireless inspection by the TTMC in the approaching zone and has been granted bypass privileges. It displays the date and time of the inspection as well as specific carrier and vehicle information that can be used in case the truck needs to be identified as it passes by.

A screen shot of the bypass notifier is shown in figure 18.

Figure 18 (Screen Shot) screen of Bypass Notifier

MAPPING APPLICATION

To enhance the experience at the demonstration a mapping application was used. It displayed the real time location of the truck as it drives the three passes of the demonstration route around the Volvo campus. A screen shot of the mapping application is shown in figure 19.

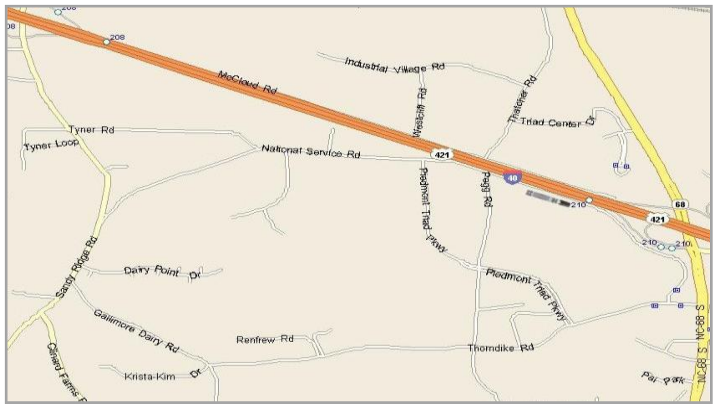

Figure 19 (Screen Shot) Mapping Application

ON BOARD COMPONENT (OBC)

The on board component (OBC) collects data from the various systems on the truck, including data from the internal vehicle data bus as well as from externally installed systems such as the tire pressure monitor. The OBC then reports the data through a cellular modem to the TTMC, including location data from a GPS receiver. The results of the wireless inspection are displayed to the driver in a non- disruptive way using a pop-up display in the dashboard of the cab.

A picture of the pop-up display is shown in figure 20.

Figure 20 (Photograph)
OBC Pop-up display

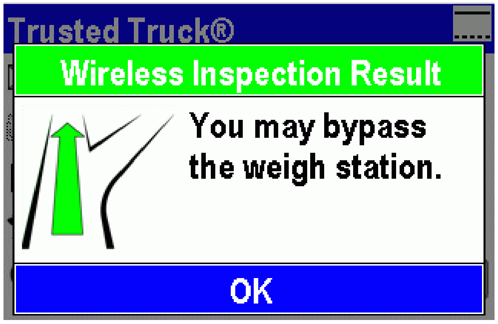

Figure 21 (Screen Shot) "Bypass" message

If the wireless inspection results in a passed inspection, a message is sent from the TTMC to the OBC resulting in a display on the pop-up display prompting the driver to bypass the inspection station.

A screen shot of the "bypass" message is shown in figure 21.

If the wireless inspection results in a failed inspection, a message is sent from the TTMC to the OBC resulting in a display on the pop-up display prompting the driver to enter the inspection station.

A screen shot of the "enter" message is shown in figure 22.

Figure 22 (Screen Shot) "Enter" message

CHAPTER 7. TESTING

Unit testing was performed as the various system units were completed, for example the in-cab display unit was tested independently of the TTMC application. As the system components were completed, a gradual integration of the complete system eventually led to system testing of the complete wireless inspection process. Finally, the system was tested by dry runs of the entire demonstration.

CHAPTER 8. DEMONSTRATION

The final demonstration of the functionality was performed on April 25th at Volvo US Headquarters in Greensboro, NC. The event successfully demonstrated the implemented functionalities of the Year 1 effort. The conference room used for the presentations and demonstration facilitated three large projection screens displaying

1. The TTMC (front large screen)
2. The bypass notifier (front left smaller screen)
3. The mapping application (left large screen – not in the picture)

The setting also enabled the audience to see the demonstration truck both bypass and pull into a simulated inspection station through large windows from the conference room. A picture of the set up is shown in figure 23, including the TTMC shown on the big screen in the front and the Bypass notifier on the smaller screen in the left front corner. A third screen displayed the mapping application on left side (not in this picture).

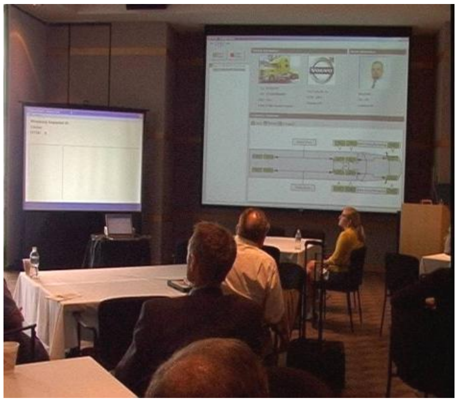

Figure 23 (Photograph) TTMC Demonstration Set-up

A detailed presentation of the technologies and demonstrated a past, present and future view of the program was presented. This was followed by a lively Q&A session.

The presentations were followed by three demonstration runs of the truck as described below:

1. The truck has no faults and passes the wireless inspection. The automatic response is enabled at the TTMC and the driver gets the in-cab prompt to bypass the inspection. The bypass notifier is showing station personnel that “trusted” truck has been allowed to bypass the station.
2. The truck has a brake fault and does not pass the wireless inspection. The automatic response is enabled at the TTMC and the driver gets the in-cab prompt to enter the inspection station. The bypass notifier does not indicate anything that could identify the truck, which enters the station as part of the general population of trucks on the highway.
3. The truck has a light fault and does not pass the wireless inspection. The automatic response is not enabled at the TTMC and the TTMC operator initiates a message to the truck, giving the driver the in-cab prompt to enter the inspection station. The bypass notifier does not indicate anything that could identify the truck, which enters the station as part of the general population of trucks on the highway.

Between the first and second demonstration run the audience was invited to walk out to the truck and witness the nature of the faults being generated in the truck. Several members of the audience also entered the truck to see the in-cab messages and also rode with the truck during the last two demonstration runs.

CHAPTER 9. CONCLUSION

LESSONS LEARNED

- The GSM data coverage for the GPRS and EDGE technologies is generally good in the areas of the Volvo campus as well as near the Greene County inspection station.
- The importance of the TTMC and its third party operation is to create a neutral player endorsed by industry and enforcement. This creates winning incentives for all parties.
- Technologies successfully implemented:
    - Cellular wireless link (GPRS). The coverage was very good at all locations tested, including the inspection station in Greene County, Tennessee
    - GPS location (WAAS)
    - Vehicle data buses J1587 and J1939
    - In-dash display for messages to the driver. This proves to be a non- intrusive medium to safely deliver limited information to the driver
    - Tire pressure and temperature system for Tractor
    - Brake’s lining and stroke data from Tractor
    - Brake stroke data from Trailer
    - Fire extinguisher general and pressure status
    - Seatbelt status
    - Driver login
    - In-dash pop-up TFT display
    - TTMC
    - Bypass notifier

NEXT STEPS

The Trusted Truck® Program is moving forward toward its goal of removing unnecessary stops for inspections by establishing "trust" in individual trucks and carriers, as well as in the entire Trusted Truck® process, through wireless inspections. Several options can be identified as potential next steps for the program, and some examples are listed below.

Examples of next steps (Phase B):

- Added data for trailer and tractor
  - Weight of Vehicle and Trailer
  - Tire pressure and temperature for Trailer
  - VIN from Trailer
- Manifest Data associated with Trailer VIN
- Investigations:
  - Traffic data
  - Traffic light priority
    - GPRS latency (for traffic light priority)
  - Trailer communications
    - Specifically for lights and door monitor
  - Include look-up data from USDOT databases

Possible future steps (Year 3, 4 and beyond)

- Connection to systems and databases at the carrier and fleet operators
- Data communication security (encryption and certificate authority)
- Security/Hazmat: Route Monitoring
- Intra/inter-state collaboration
- Tamper proofing/cargo seals/Trailer door monitor
- Biometric driver ID verification
- EOBR
- Manifest Data
- Traffic Flow data
- DSRC migration, VII alignment
- Cellular high speed data
- Enforcement identification
- Inspection station collaboration:
  - Intra-state
  - Interstate
- Trusted Truck® Business case (TTMC third party provider)
- FOT (Field Operation Test)

CHAPTER 10. REFERENCES

FHWA/FMCSA. (2004, September). *http://www.its.dot.gov/jpodocs/repts_te/13981.htm.* Retrieved from www.its.dot.gov.

FMCSA, J. L. (2006, January). *http://www.itsa.org/itsa/files/presentations/cvfmwirelessinspectionsloftus.pps.* Retrieved from www.itsa.org.

ITRE, C. V. (2006, November). Retrieved from North Carolina State University Institute for Transportation Research and Education (ITRE): http://www.itre.ncsu.edu/vams/cvs/documents/i-95wirelessinspectionstudy_finalreport.pdf

Video: VTA, UTK. (2006). HTTP://NTRCI.ORG/TEMPLATE_ASSETS/VIDEO/TRUSTEDTRUCK.MOV. Retrieved from www.ntrci.org.