Automation Technologies for Commercial Vehicle Safety Screening

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Abstract
Road agencies are mandated to improve highway safety for all users while maintaining efficient use of the highway infrastructure. Automated inspection technologies have been developed to assist agencies in their objectives, typically including the use of weigh-in-motion sensors coupled with various vehicle identification technologies to allow compliant commercial vehicles to bypass inspection facilities. While weigh-in-motion sensors are effective at screening for overweight vehicles, new sensor technology is offering the ability to screen for other safety defects at highway speed. This paper describes several of these new technologies: tire anomaly and classification systems, hazardous materials placard reader systems, automated thermal imaging systems, and under vehicle area scanning.

Keywords
Asset Management, Traffic Monitoring, Traffic Data

Introduction
Mechanical inspection of 100% of commercial vehicles is not possible due to constraints at inspection facilities. With limited space to inspect vehicles and limited staff available to conduct the inspections, various methods of automated inspection are being integrated into commercial vehicle operations. The first automated inspection technology to gain widespread acceptance was weigh-in-motion (WIM). Adopting WIM allowed agencies to bypass vehicles that were below a gross vehicle weight that the agency determined as posing a safety risk, or that could create excessive infrastructure damage. Allowing these vehicles to bypass the inspection station reduced the space needed at inspection stations for parking and physical inspections. Additionally, bypass systems reduce backups (queuing) at busy inspection stations. Backups and idling in queues at stations that didn't utilize bypass systems increased costs and greenhouse gas emissions for carriers and presented collision hazards when backups extended onto the main road.

Today, WIM bypass systems have evolved to include a wide variety of other automated inspection technologies. The WIM systems' roadside electronics, which once only passed weights to the inspection station, are now powerful roadside computers capable of controlling a wide variety of sensors and peripheral equipment. Individual vehicles can be identified and checked against their previous inspections and safety records (or their company's safety records). The vehicle's credentials can also be checked against government databases. The technologies that make this possible include RFID, GPS, mobile technologies, and automated number plate readers (ANPR).

Even with these technologies at the disposal of commercial vehicle enforcement agencies, there is still a need for frequent scheduled or random vehicle inspections to ensure road safety. As agencies seek to better deploy resources, new automated inspection technologies are developed to enhance the efficiency and safety of commercial vehicle operations. Several new technologies offer the ability to screen for safety defects at, or near, highway speeds:

- Tire Anomaly and Classification Systems
- Hazardous Goods Identification/Tracking Systems
- Automated Thermal Imaging Systems
- Automated Under Vehicle Area Scanners

Automation Technologies for Commercial Vehicle Safety Screening

Tire Anomaly and Classification System (TACS)

The Tire Anomaly and Classification System (TACS) screens commercial vehicles at weigh station facilities to identify those vehicles which are unsafe due to missing or under-inflated tires. Additionally, TACS is able to sense lane position, enabling agencies to monitor for vehicles that deviate from their lane and present a hazard to other road users or infrastructure.

TACS supports the screening of commercial vehicles at highway (up to 160 km/h) and ramp speeds (down to 1 km/h) at weigh station facilities to identify those vehicles which are unsafe due to missing or underinflated tires. In addition, TACS supports the identification of vehicles which are using wide based tires (super singles) and detects single/dual tire configuration for enhanced classification. The system identifies vehicles which meet these criteria and provides the ability for station operators to select identified vehicles for inspection.

TACS uses proprietary in-road tire and axle sensors that connect via the sensor interface electronics to the roadside electronics. A minimum of two of the in-road sensors, spaced eighteen inches apart, are required. Additional sensors may be provided to support system redundancy and tire and axle measurement in slow speed and/or stop and go traffic. The TACS system also requires one or two inductive loops for vehicle length and classification measurements.

Figure 1 – In-Road Tire Sensor Test Installation

The roadside electronics connect to and communicate with the inspection station’s operator workstation. The vehicle record appears on the operator’s computer display in near real time. The operator display software provides a graphical representation of each vehicle, based on its axle and tire configuration. Each vehicle’s record includes: vehicle speed, axle spacing, vehicle classification, tire width, identification of tire type (single, dual, wide-base), axle width, and position of the vehicle in the lane. Operators are notified of safety issues with alerts for underinflated tires, overinflated tires, and missing/flat tires.

Automation Technologies for Commercial Vehicle Safety Screening

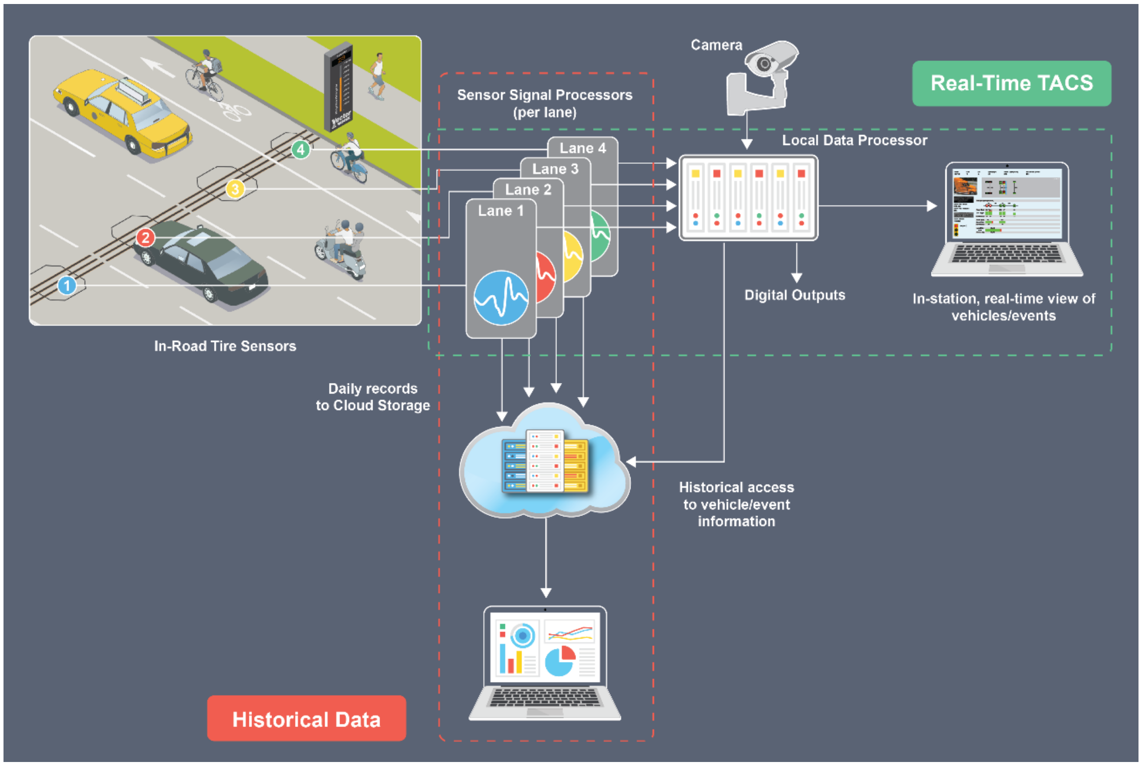

Figure 2 – Schematic Representation of the TACS System

Central Data Repository – Historical Data

The in-road sensors, sensor processing electronics and the TACS local data processor create daily records of all observed vehicles and events. The data is stored in a cloud-based data repository, and users access the data through a web-based user interface.

In addition to data on the aforementioned tire characteristics, the in-road tire sensors used in TACS are able to provide agencies with historical data on lane position. Infrastructure asset management is a vital function for agencies overseeing road systems. Calculations for roadway design and maintenance make use of traffic data inputs such as vehicle classification and load data to assist in making current and future plans. Precise, long-term data on vehicle lane position and distribution of wheel paths along the width of the lane will provide information on expected wear patterns.

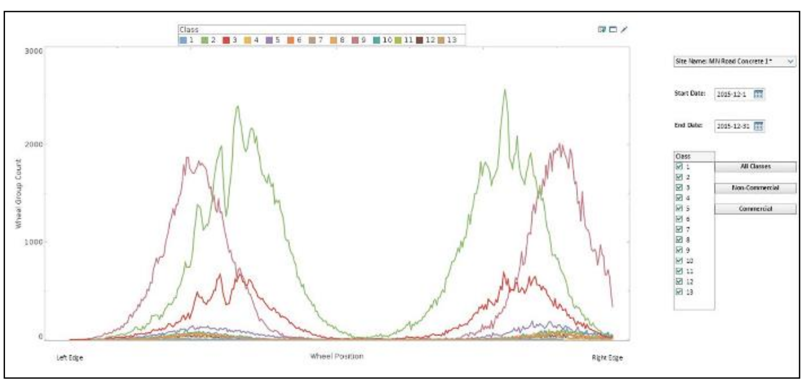

Figure 3 – Wheel Path Data Visualization

Automation Technologies for Commercial Vehicle Safety Screening

Hazardous Goods Identification and Tracking

Hazardous materials and dangerous goods transportation presents unique risks to other road users and the public at large. Agencies often establish special routes for vehicles placarded for hazardous goods transport which avoid heavily populated areas, narrow streets, and tunnels. An image capture system which is optimized for automatic HAZMAT identification is a suitable automated method of checking that commercial vehicles are following permitted routes.

HAZMAT placards are diamond-shaped placards that are mounted on transport trucks and trailers carrying dangerous goods or hazardous materials. The placards provide information to first responders at incidents such as accidents or fires. Each placard has a symbol and 4-digit ID number that identifies the hazardous material being transported by the commercial vehicle.

Automated systems use a high-resolution camera, typically exceeding standard HD resolutions, to capture an image of the placard. A sensor, such as a digital laser trigger or combination of sensors that can detect and discriminate passenger and commercial vehicles, triggers the camera. The image is transferred to a ruggedized, industrial computer housed at the roadside where optical character recognition (OCR) is used to read the numbered placards. The computer also looks up the 4-digit number to identify the hazardous material.

Figure 4 – Laser Trigger (left) and HAZMAT Placard Camera and Illuminators (right)

The information from the HAZMAT identification system is appended to the vehicle record and is available to view in the operator display for comparison with the vehicle credential information. Vehicles can therefore be screened to ensure they have the correct permit to carry hazardous materials and that they are traveling the correct route.

Automated Thermal Imaging Systems

Automated thermal imaging systems use smart vision processing algorithms to automate safety inspections. Unlike thermal inspection systems requiring a human operator, an automated system evaluates every vehicle passing through and compares the thermal signatures against a set of rules generated from past inspections. For vehicles with potential safety problems, the system generates a report and forwards it to facility staff who may then pull the vehicle over for a full inspection.

Automated thermal imaging systems employ a sophisticated data fusion model that treats each vehicle as a whole. Two infrared cameras capture thermal signatures of both sides of the vehicle. Using paired axle data from an entire vehicle, the automated system assesses the condition of brakes, bearings, and tires. Decisions are not made based on what a wheel “looks like,” but rather on a complex evaluation of actual temperatures of all elements of the vehicle.

Automation Technologies for Commercial Vehicle Safety Screening

The agency benefits in two ways. First, because it does not require a dedicated operator to simply watch the screen and make judgements about what may or may not be a problem. Second, by applying a set of standard rules to every vehicle, the system focuses inspector's attention on only those vehicles that have a known correlation to safety concerns.

Figure 5 – Infrared Cameras and Thermal Imaging System Enclosure

Between 2013 and 2015, brake problems were identified as a contributing factor in more than 20% of fatal large truck accidents in the United States where the vehicle-related factor was reported.[1] Current inspection practice can only evaluate the brakes of a small fraction of vehicles on the highways. Placing a thermal imaging system along an entrance roadway to a fixed inspection site will increase the percentage of vehicles that are screened for possible brake problems. Suspect brakes are too hot, which indicates a dragging brake condition, or too cold, which suggests a particular brake is not working when it should be.

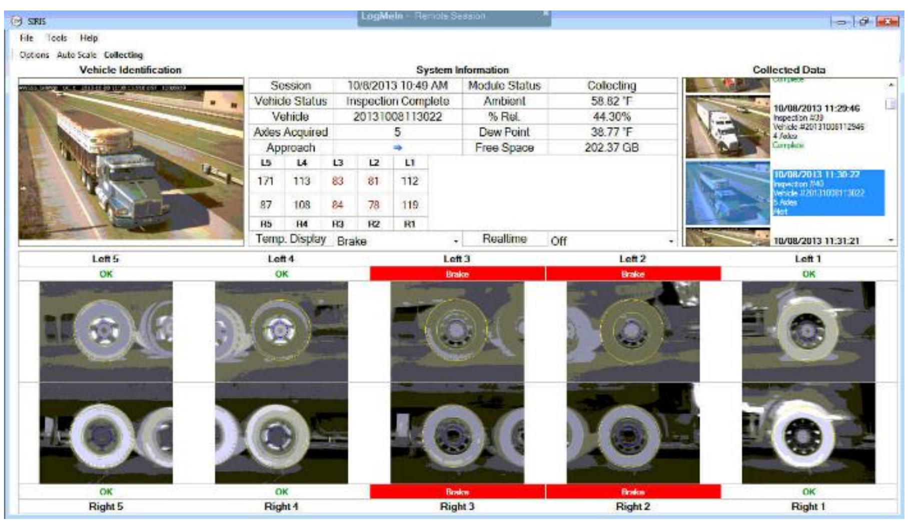

Figure 6 – Automated Thermal Imaging System: Low Temperature Brake Alert

Automated thermal imaging systems successfully identify vehicles with overheated bearings. While overheated bearings are not a particularly frequent problem during commercial vehicle inspections, a poorly lubricated bearing can rapidly lead to catastrophic failure of a wheel resulting in a fire, a seized bearing that could drastically alter the handling capability of the vehicle, or loss of the entire wheel. In the latter situation, innocent travelers have been killed when a truck wheel crashed into their vehicles.

Automation Technologies for Commercial Vehicle Safety Screening

The tire forms the crucial connection between the vehicle and the road surface. Faulty tires undermine the integrity of that connection and present a very real hazard to the truck and others on the highway. Thermal imaging systems are able to detect tires that are underinflated, that have exposed radial steel belts, and that have partial delamination of tread. Problems seen in tires can also be an indicator of other issues, such as poorly distributed loads and problems with air suspension systems.

Automated Under Vehicle Area Scanners

Automated under vehicle area scanners (UVAS) use color and/or black and white area scanning technology to effectively scan and inspect the undercarriage of vehicles to search and analyze images for explosive devices, suspicious objects or contraband such as drugs and weapons.

The system uses area scan technology that captures images at up to 900 frames per second. This enables image capture of the entire length of the vehicle at speeds up to 75 km/h. While this is not full highway speed, safety screening can be done in a speed restricted area of the main roadway without requiring vehicles to report to an inspection station. The UVAS may also be installed on the ramp approach to the inspection station.

Figure 7 – Under Vehicle Area Scanner

The UVAS scan produces an image of the full undercarriage of the vehicle being screened, with no limit on vehicle length. At inspection stations these images may be monitored by an experienced vehicle inspector and used to check vehicles for damage to the undercarriage, allowing a higher volume of vehicles to be examined for safety concerns than would be possible using traditional pit inspections.

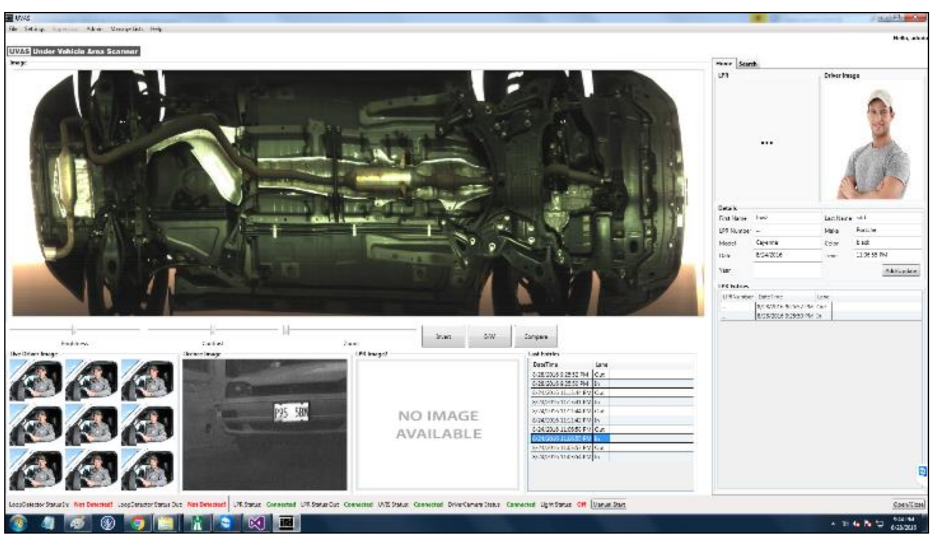

Figure 8 – Under Vehicle Image Shown on Operator Display

Automation Technologies for Commercial Vehicle Safety Screening

Automated anomaly detection software enables automated screening for contraband and explosives using the UVAS hardware. The anomaly detection software checks the image of the underside of a vehicle against an established safe vehicle. Any anomalies are flagged for further inspection by a human operator.

Conclusion

Automated vehicle inspection at commercial vehicle operations has moved beyond weight and credential screening to include other inspection technologies that utilize roadside computers, machine vision, newly developed sensors, cloud computing and customized operator displays. In addition, historical records offer agencies the ability to plan based on statistical analysis. Agencies are looking for information that can aid in the monitoring of heavy vehicles for safety issues, provide source/destination information associated with freight movements, and not only protect infrastructure but also assist in planning for infrastructure improvements. The next generation of automated inspection technologies will offer all of these benefits while maintaining or improving the efficiency of commercial vehicle operations.

References

1. Analysis Division of the Federal Motor Carrier Safety Administration (2016). *Large Truck and Bus Crash Facts,* Federal Motor Carrier Safety Administration.