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Revenue Service Evaluation of a Truck Component Inspection System

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14. ABSTRACT

The Federal Railroad Administration, in collaboration with the Association of American Railroads and project coordinator Transportation Technology Center, Inc., has sponsored a revenue service test of an automated, machine vision inspection system for evaluating truck components on railcars. The system was from KLD Labs of Hauppauge, NY, and installed at the Hague site on CSX railroad property. This represents the second phase of a two-phase project. In Phase 1, the inspection system was evaluated at the Transportation Technology Center in Pueblo, CO, where algorithms were developed and a manual data viewer was created. This interim report is published at the midway point of Phase 2, where the revenue service system was installed and is now operational. Testing is currently underway. The manual data reviewer is being applied to in-service traffic while inspection algorithms are being updated and tried out on a wide variety of freight rail vehicles.

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Automated inspection, truck component inspection, axle spacing measurement, maintenance planning

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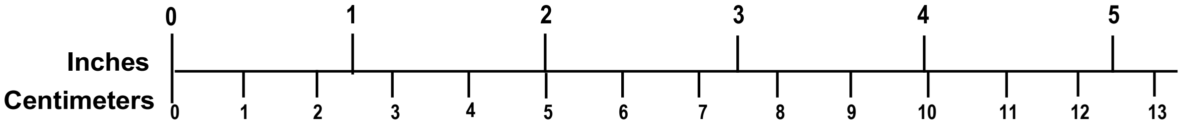
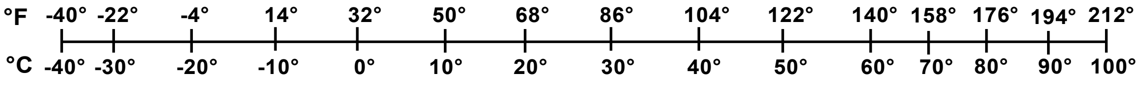
METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC	METRIC TO ENGLISH
LENGTH (APPROXIMATE)	**LENGTH** (APPROXIMATE)
1 inch (in) = 2.5 centimeters (cm)	1 millimeter (mm) = 0.04 inch (in)
1 foot (ft) = 30 centimeters (cm)	1 centimeter (cm) = 0.4 inch (in)
1 yard (yd) = 0.9 meter (m)	1 meter (m) = 3.3 feet (ft)
1 mile (mi) = 1.6 kilometers (km)	1 meter (m) = 1.1 yards (yd)
	1 kilometer (km) = 0.6 mile (mi)
AREA (APPROXIMATE)	**AREA** (APPROXIMATE)
1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)	1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)	1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)	1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)	10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres
1 acre = 0.4 hectare (he) = 4,000 square meters (m^2)	
MASS - WEIGHT (APPROXIMATE)	**MASS - WEIGHT** (APPROXIMATE)
1 ounce (oz) = 28 grams (gm)	1 gram (gm) = 0.036 ounce (oz)
1 pound (lb) = 0.45 kilogram (kg)	1 kilogram (kg) = 2.2 pounds (lb)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)	1 tonne (t) = 1,000 kilograms (kg)
	= 1.1 short tons
VOLUME (APPROXIMATE)	**VOLUME** (APPROXIMATE)
1 teaspoon (tsp) = 5 milliliters (ml)	1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 tablespoon (tbsp) = 15 milliliters (ml)	1 liter (l) = 2.1 pints (pt)
1 fluid ounce (fl oz) = 30 milliliters (ml)	1 liter (l) = 1.06 quarts (qt)
1 cup (c) = 0.24 liter (l)	1 liter (l) = 0.26 gallon (gal)
1 pint (pt) = 0.47 liter (l)	
1 quart (qt) = 0.96 liter (l)	
1 gallon (gal) = 3.8 liters (l)	
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)	1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)	1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)
TEMPERATURE (EXACT)	**TEMPERATURE** (EXACT)
[(x-32)(5/9)] °F = y °C	[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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Executive Summary

In collaboration with the Association of American Railroads' (AAR) Strategic Research Initiatives (SRI) Program, the Office of Research, Development and Technology of the Federal Railroad Administration contracted Transportation Technology Center, Inc. (TTCI) to perform research relating to the application of an advanced machine vision (MV) technology for the inspection of railcar components. Of particular interest in this study is the inspection of the components of the railcar truck or bogie. The report also provides updates to the manual data viewer that was developed in Phase 1 of the project, which is a manual data reviewer interface for humans to evaluate images from the MV system. The viewer is used by expert inspectors to evaluate component condition, and markups are automatically saved. In Phase 2, a KLD truck component inspection system was installed on CSX railway at the Hague site south of Waycross, GA. The true variety of components and conditions are being captured and documented for the benefit of improving the automated inspection capability of MV systems. This interim report summarizes the installation, commissioning, and preparation of the system for testing in the revenue service environment. Subsequent reports will document the inspection performance of the system.

1. Introduction

In collaboration with the AAR SRI Program, FRA is sponsoring research aimed at advancing the state of MV technologies for railroads. FRA is working with TTCI to evaluate and progress a truck component inspection system. This a wayside MV inspection system automatically photographs and evaluates the truck components within its view. Inspections include axle spacing measurements, missing bearing end cap bolt detection, broken and missing spring detection, and bolster spring height measurement.

1.1 Background

Automated railcar inspection systems have been under development for several years. Previous FRA testing to demonstrate automated inspection of safety appliances revealed that normal variations in railcar components (manufacturer, model, type, etc.) can confound image analysis algorithms. MV systems must be programmed to recognize defects and out-of-specification conditions. In general, the commercial vendors that code up the inspection algorithms for evaluating component condition are not train inspection experts. Consequently, inspection automation can be an inefficient process of trial-and-error. A way to address this shortcoming is to better answer the first question of every algorithm developer: what does a defect look like? This question was addressed in the first phase of this project, where a manual reviewer interface was developed. The manual reviewer provides a means for train experts to view images from the MV system and store their inspection knowledge along with the images. In this second phase, the test system and the manual viewer have been deployed at a revenue service site. Here, the true variety of components and conditions can be captured and documented for the benefit of improving the automated inspection capability of MV systems.

1.2 Objectives

The overarching objective of this research project is to advance MV inspection for the safety and efficiency of the railroads. To achieve this, TTCI has proposed a two-phased project. The main objective of Phase 1 was to develop specifications and demonstrate the concept for a manual reviewer interface. This interface was initially tested by TTCI using data from MV systems undergoing testing at the Facility for Accelerated Service Testing (FAST) at the Transportation Technology Center (TTC). In this second phase, the truck component inspection system was migrated to revenue service. There, the manual data reviewer is being applied to in-service traffic while inspection algorithms are being tried out on a wide variety of freight rail vehicles.

1.3 Overall Approach

In the previous phase, TTCI established the functionality of the manual reviewer and confirmed the intended operation of the KLD truck component inspection system. In this second phase, TTCI migrated the system to a revenue service site. The site is on the CSX railroad at the Hague supersite south of Waycross, GA. Testing in revenue service was expected to help enhance algorithm pattern-recognizing capabilities. Such testing exercised the existing inspection algorithms on a wider variety of traffic and defect types. It also provided a larger reference population for algorithm development than was available with the test traffic at TTC. To complete the development, TTCI is modifying the data viewer for compatibility with CSX standards. TTCI anticipates completing the testing and evaluation of the system on schedule by the end of third quarter 2018.

1.4 Scope

The scope of this interim report is limited to describing the installation and startup of the KLD truck component inspection system at the CSX Hague supersite in Waycross, GA and to describing updates to the manual viewer that were required as a result of the deployment at CSX. This preliminary update precedes performance results reporting which will be part of the final project report.

1.5 Organization of the Report

Section 2 describes the truck inspection system and installation.

Section 3 describes upgrades to the manual reviewer configuration and data evaluation.

Section 4 presents planned tests.

Section 5 describes the continuing direction for project completion.

Section 6 contains the conclusion of this report.

2. KLD Truck Inspection in Revenue Service

KLD installed a truck component inspection system on CSX track at the Hague site south of Waycross, GA. This wayside inspection system automatically photographs and evaluates the truck components within its view. It was installed in December of 2016 and commissioned immediately thereafter. The following sections document the installation and startup.

2.1 System Installation

In December 2016, KLD installed the system at the Hague site on and adjacent to CSX track. The truck component inspection system is comprised of two subsystems, or modules, called Truck Scan (TS) and Axle Scan (AS). The two modules provide different camera views of the truck components. TS is centered on the spring nest and components at the center of the side frame. The AS views the ends of each axle and the associated components in this area of the truck. The system as installed at the Hague site was identical to the one at TTC.

Per the KLD requirements, CSX installed pylons beside the track to provide a foundation for the equipment stanchion. The type of pylon selected did not require concrete. Instead, a hole was dug and the pylon was driven into position. Figure 1 depicts installation of the pylons.

Figure 1. Installation and Leveling of the Foundation Pylons for the Camera Stanchions

After backfill, the stanchions were positioned for installation on the pylons. Distance to the track must be known precisely so that component sizing is accurate within the images. Figure 2 shows the installation team positioning the stanchions prior to bolting them down.

Figure 2. Installation Team Positioning Stanchions

Once the stanchions were situated, the bases were marked so holes could be drilled in the required location. Figure 3 shows the markings.

Figure 3. Bases Marked and Holes Drilled to Maintain the Exact Distance from the Rail

Distance from the rail head to the top cross member was determined using a string line. The stanchion was then marked for the required camera height. Figure 4 shows the marking of camera height.

Figure 4. Camera Height Set a Known Distance above the Rail

One conduit was required under the track for feeding wires to the far side. An existing conduit was used for this purpose. Figure 5 shows the junction box on top of this conduit.

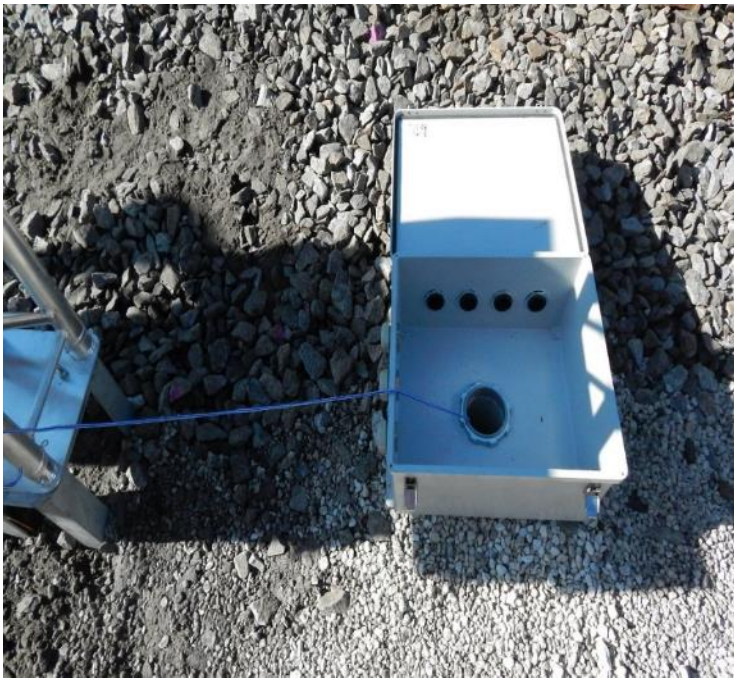


Figure 5. Junction Box on the Conduit from the Far Rail

Figure 6 shows workers installing the cameras on one side of the track. The control bungalow is visible in the background.

Figure 6. Installation of Axle-level Cameras at Hague Site

Figure 7 shows an image of the nearly completed system, with cameras mounted on both sides of the track.

Figure 7. Nearly Completed System Showing All Cameras in Position

Precise triggering of the cameras is required to assure the components are centered in the camera view. Triggering is provided by wheel sensors mounted to the rail. Holes were drilled and the sensors mounted on each rail. Figure 8 shows the sensors mounted to the near rail.

Figure 8. Wheel Sensors Mounted on Each Rail for Precise Triggering of Cameras

2.2 Commissioning and Calibration

Image processing requires knowing the physical size and location of elements within the image frame in terms of pixels. KLD has developed a calibration procedure where precision targets are placed at known locations so that pixel mapping to known features can be performed. Figures 9 and 10 show the calibration target and the resulting image.

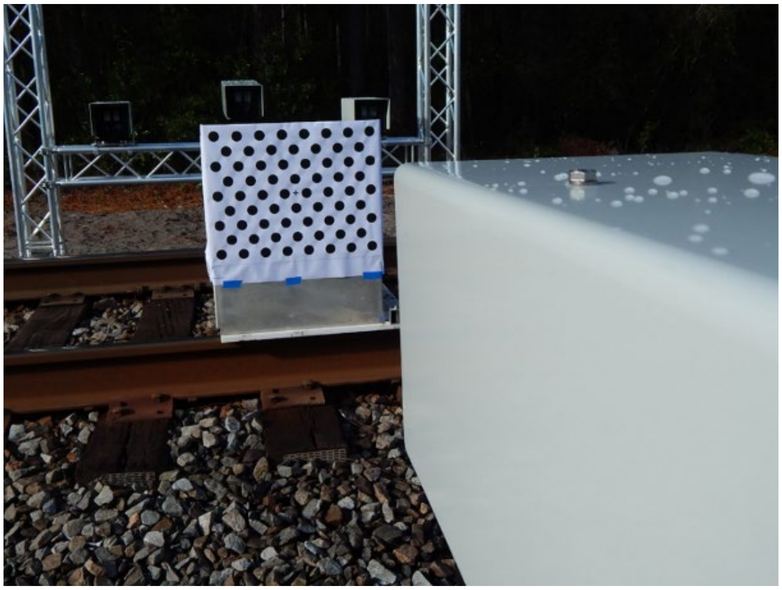


Figure 9. Calibration Target at a Known Distance and Location from the Camera

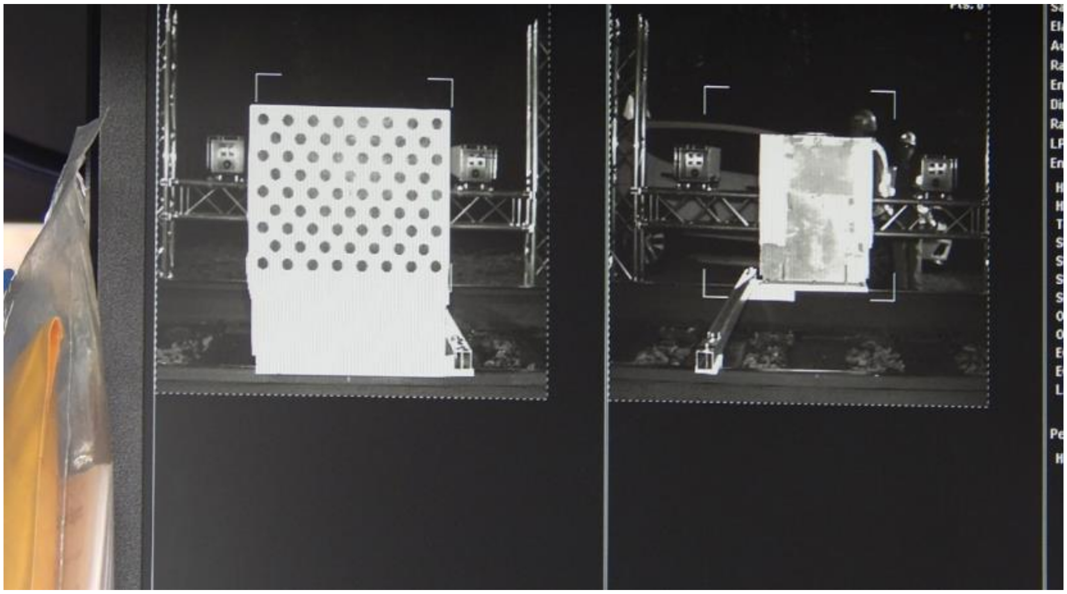


Figure 10. Calibration Targets as Imaged by Opposite Cameras

Adjustments were made until the target sizing and placement in the image was correct. Figure 11 shows the workman adjusting the camera aim.

Figure 11. Cameras Adjusted to Align the Image in the Camera Field of View

2.2.1 System Commissioning

The KLD truck component inspection system consists of two subsystems, AS and TS. The AS system images are centered around the axle center, showing the end cap, bearing adapter, ends of the side frames, and wheel. The TS system produces images of the central components of the truck, namely the springs, bolster, friction wedges, and side frame central casting. Figure 12 shows example images from both of the systems.

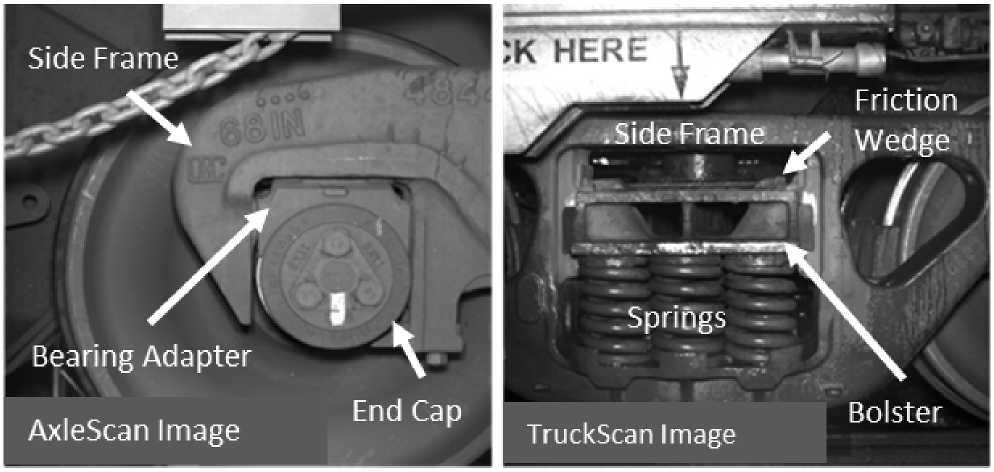


Figure 12. Example Images from the AS and TS Modules

Shortly after installation, KLD commissioned the system and it began producing images.

Although the system was operational upon installation, it did experience a few growing pains shortly after commissioning. Train presence sensors that were to be provided by CSX were not compatible with KLD hardware. As such, the system remained "on" even when trains were not present. This really did not present a problem for the experiment, but it was wasteful of system resources. KLD and CSX will address this issue. About 5 months after installation, a wheel sensor came loose, causing issues with both modules. CSX was able to repair the problem and restore system operation.

Subsequently, the system began generating a large number of false positive reports. The false positive issue was believed to be software-related and is being addressed by KLD. An unexpected result was that a large number of error reports were being sent with images. This overcrowded the information bandwidth. As a result, KLD temporarily suspended sending any reports, resulting in no train reports, either. Later, they resumed sending reports without images. Images could still be retrieved from the KLD server manually for the manual viewer but were not immediately required, as the viewer was undergoing updates at the time. The next section addresses updates to the manual viewer.

3. Manual Reviewer Upgrades

In Phase 1 of the project, TTCI developed a manual data viewer for the KLD MV inspection system located in Section 1 of the High Tonnage Loop (HTL) at FAST. The data viewer allows expert users to evaluate freight car component images and exception reports from the KLD truck component inspection system. In Phase 2, work continued toward upgrading and optimizing the manual viewer so it would work seamlessly with data from both the FAST and Hague systems.

3.1 Manual Reviewer Configuration for CSX

The original plan called for the viewer interface to be carried over directly from the FAST site to the Hague site. However, KLD made changes to their data specs and FTP data transfer protocol to accommodate CSX requirements. These changes were made to both inspection modules, AS and TS. Thus, the manual viewer required substantial updates to be compatible with the requirements at Hague.

To accommodate the changes, TTCI upgraded the manual reviewer so it is optimal for use with both the FAST and Hague site systems. A user could now filter either FAST or Hague data for viewing and vetting. Figure 13 illustrates the upgraded manual viewer as deployed with the KLD system at FAST as well as at the Hague site. Figure 14 shows the new "Detector Site" built-in filter (circled in red) that allows users to review the data coming from either the FAST or the Hague site.

Thereafter, the new data loaders for CSX data were designed and tested. Data transfer from the Hague site is programmed to automatically occur after each passing train in near-real-time. Summary exception reports and corresponding images are transferred to the TTCI server as soon as they are generated, and expert users have instantaneous access to the data.

To secure CSX data while being regularly transferred from the Hague site to the viewer server at TTC, TTCI requested that the data be encrypted at all times and that data records be accessible only with a TTCI-provided password.

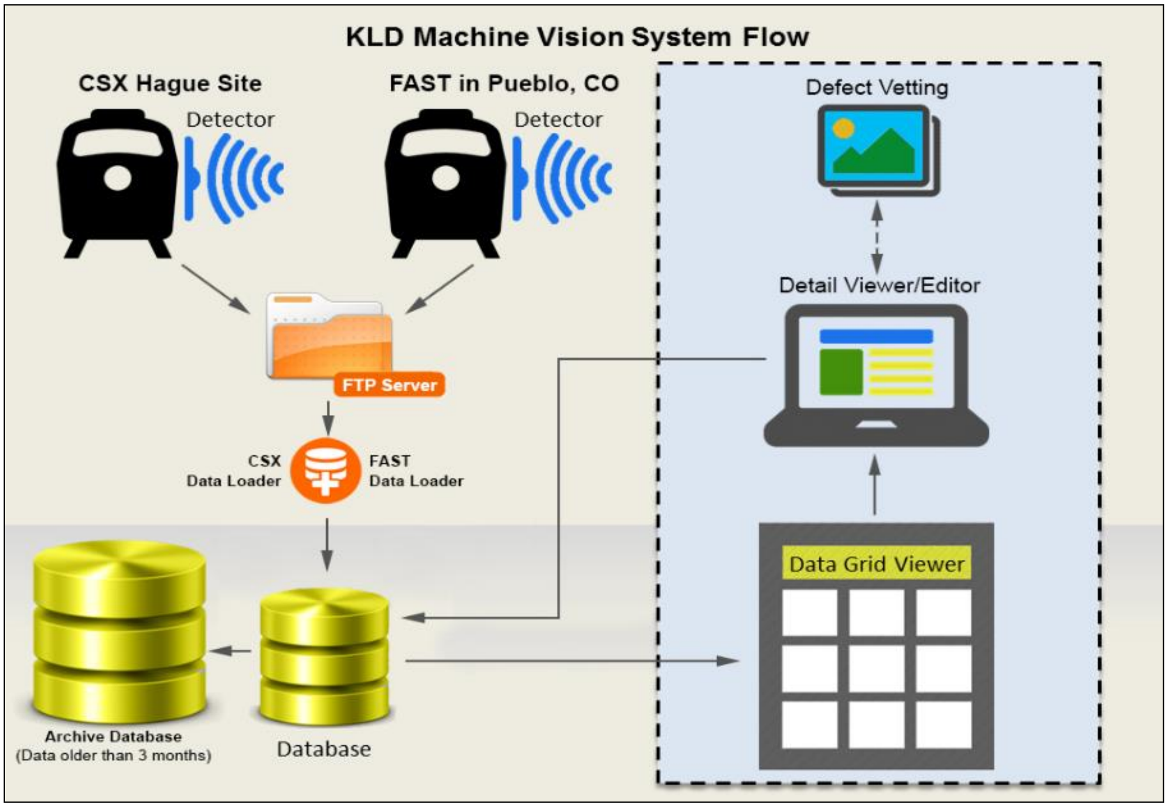
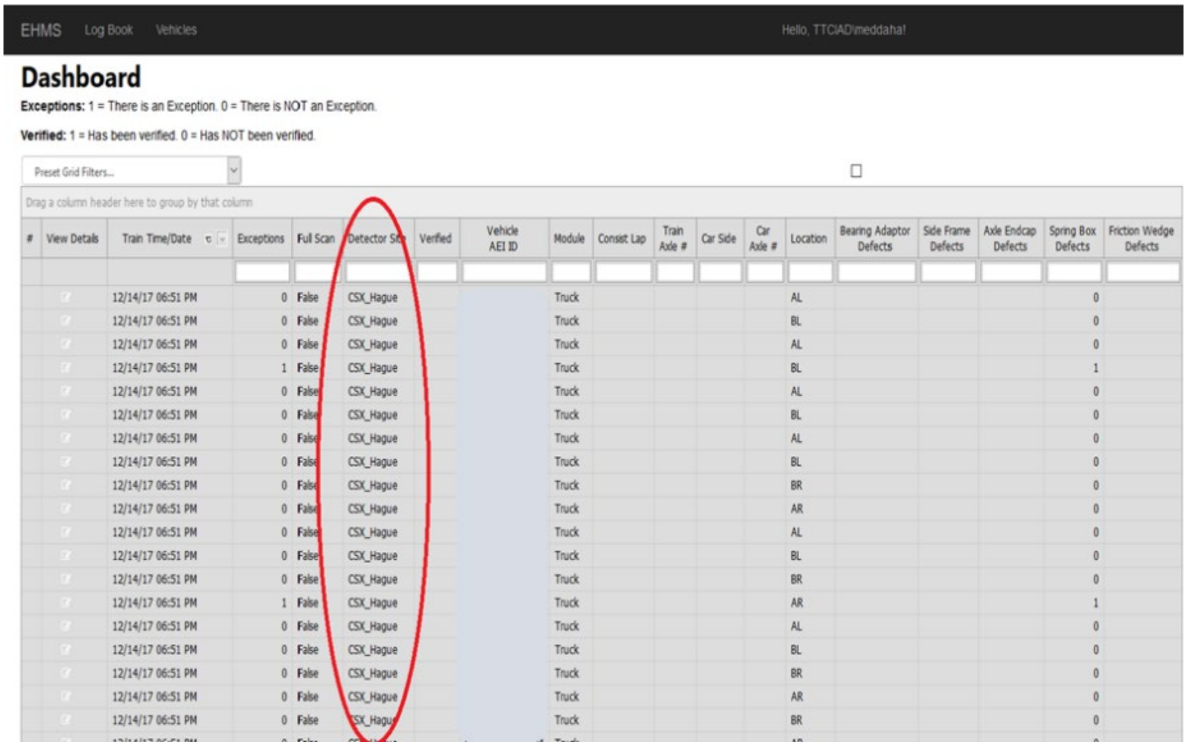


Figure 13. MV Manual Viewer with FAST and Hague Site Monitoring Systems



Dashboard

Exceptions: 1 = There is an Exception. 0 = There is NOT an Exception.

Verified: 1 = Has been verified. 0 = Has NOT been verified.

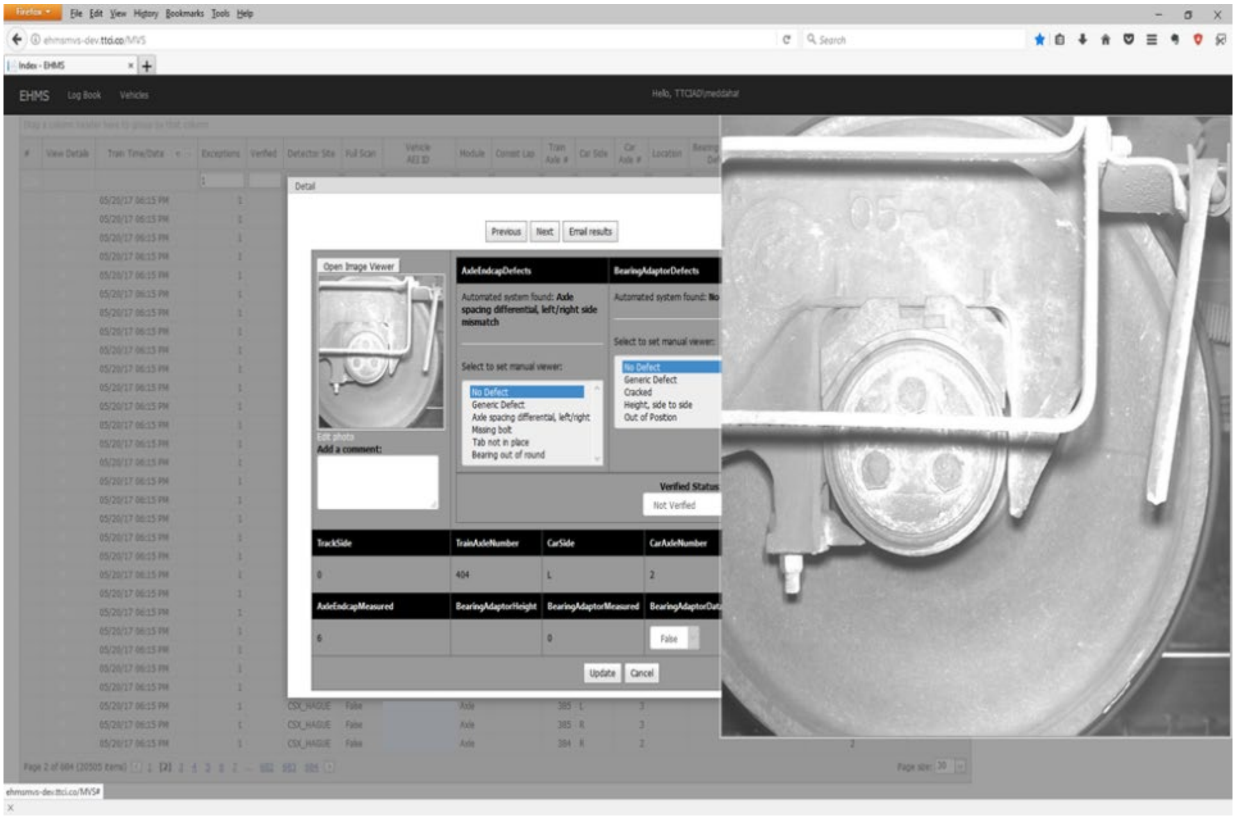
#	View Details	Train Time/Date	Exceptions	Full Scan	Detector Site	Verified	Vehicle AEI ID	Module	Consist Lap	Train Axle #	Car Side	Car Axle #	Location	Bearing Adaptor Defects	Side Frame Defects	Axle Endcap Defects	Spring Box Defects	Friction Wedge Defects
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					AL				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					BL				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					AL				0	
		12/14/17 06:51 PM	1	False	CSX_Hague			Truck					BL				1	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					AL				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					BL				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					AL				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					BL				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					BR				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					AR				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					AL				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					BL				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					BR				0	
		12/14/17 06:51 PM	1	False	CSX_Hague			Truck					AR				1	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					AL				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					BL				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					BR				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					AR				0	
		12/14/17 06:51 PM	0	False	CSX_Hague			Truck					BR				0	

Figure 14. Manual Viewer Data Records

3.2 Data Evaluation

TTCI engineers continue to closely evaluate KLD system performance and vet the data coming from the Hague site and will continue to provide KLD with feedback as the MV system evaluation progresses. Note that the KLD algorithms deployed at the Hague site will also need improvement, as some revenue service truck types differ from the truck types encountered in the FAST train. Consequently, KLD algorithms need to be trained to recognize the new defect patterns present in the additional truck types.

Data quality is also being evaluated. Figure 15 shows a documented example of an image with overexposure. This image is from the AS module at the Hague site. TTCI has provided feedback to KLD so the problem can be addressed.



AxleEndcapDefects: Automated system found: **Axle spacing differential, left/right side mismatch**

BearingAdaptorDefects: Automated system found: **No**

Select to set manual viewer:

Verified Status: Not Verified

TrackSide	TrainAxleNumber	CarSide	CarAxleNumber
0	404	L	2

AxleEndcapMeasured	BearingAdaptorHeight	BearingAdaptorMeasured	BearingAdaptorDat
6		0	False

Figure 15. MV Manual Reviewer Documented an Exposure Issue

Figure 16 shows another documented example depicting a train presence sensor going off although no train was present at the time the image was captured. Dozens of similar images were transferred to the TTCI server and the server space was needlessly filled up. TTCI informed the KLD engineers of this issue at the Hague site. KLD suspended image transmitting until the sensors could be updated.

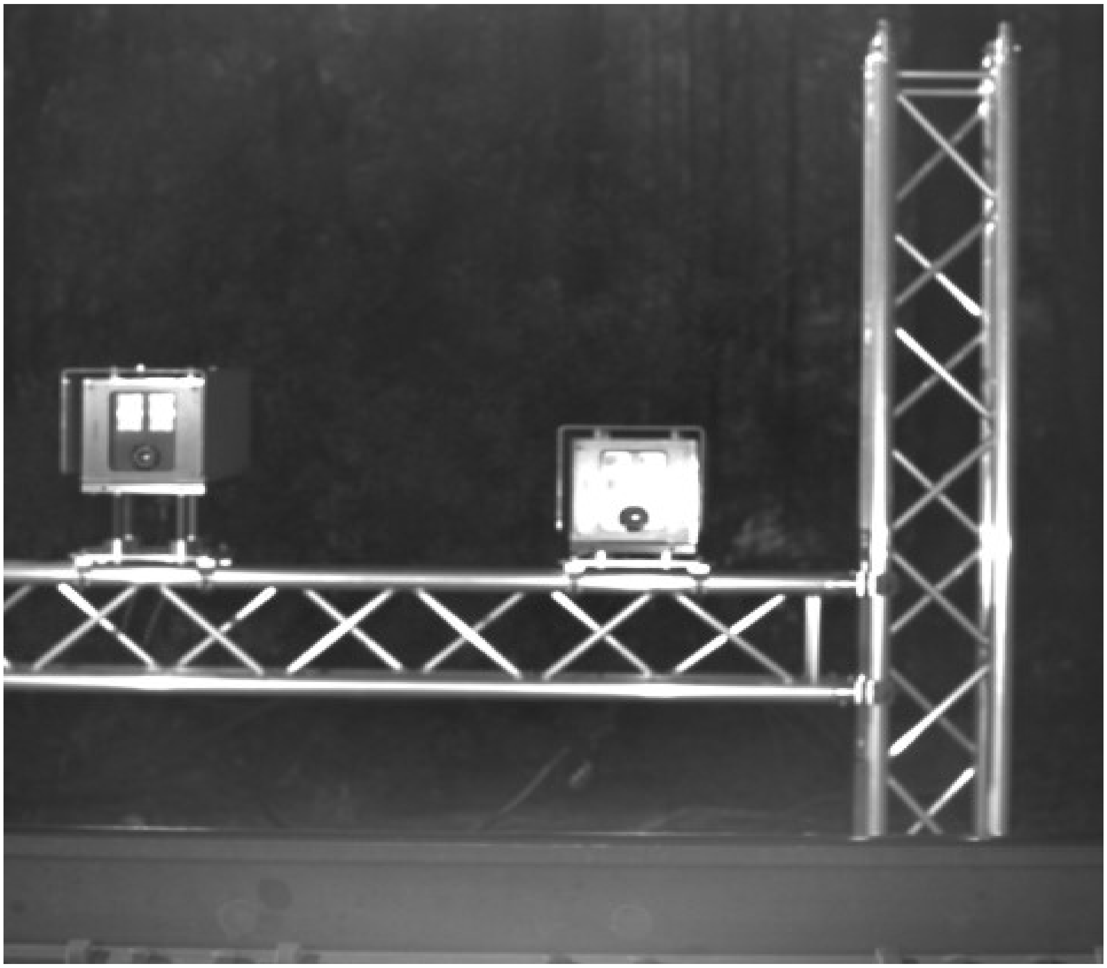


Figure 16. Train Presence Sensor Malfunction Results in Images When No Train Is Present

The two examples shown in Figure 15 and Figure 16 and similar instances could signal abnormal hardware functioning that requires maintenance attention by the supplier or railroad personnel. The manual data vetting process provides a means to identify performance issues as they occur so the supplier or the participating railroad can be notified and address them in a timely manner.

3.3 Data Automatic Archiving

MV images sent daily to the server from the two KLD systems could fill up the server disk space quickly. Over 2.5 million records have been accumulated in the viewer database thus far from both the FAST and Hague monitoring systems.

To optimize the viewer database and speed up the user experience, long- and short-term archiving procedures were designed to be integrated into the viewer. For the short-term archiving, only the most recent 3 months of records, or about 100,000 records, are kept for immediate access. Records older than 3 months are archived but remain accessible and can be queried whenever needed. For long-term archiving, all the data records older than a year are permanently deleted except for the data records that were vetted and documented. The documented records remain permanently available. The short-term archiving process was finalized and is already implemented with the database system. The coding and testing for the long-term archiving process is ongoing and is expected to be completed before the project end date in 2019

4. Planned Tests

During the final month of the project, statistics will be gathered on the operational capabilities of the system. As data is archived in the manual review database, vetted defect images will continue to accumulate and updates to the automated detection algorithms will be evaluated.

5. Continuing Direction for Project Completion

The system is functioning, and testing will continue through the duration of the period of performance. The final report will cover developments and lessons learned from operating the detection system in revenue service.

6. Conclusion

The KLD truck component inspection system at the Hague site is installed and operational. Testing is underway to demonstrate the system capability. The manual reviewer has been revamped for compatibility with the CSX system and vetted images are accumulating in the database.

Abbreviations and Acronyms

AAR	Association of American Railroads
AS	Axle Scan Module
CSX	CSX is a company name and not an acronym
FAST	Facility for Accelerated Service Testing
FRA	Federal Railroad Administration
GA	Georgia
HTL	High Tonnage Loop
KLD	KLD is a company name and not an acronym
MV	Machine Vision
SRI	Strategic Research Initiative
TS	Truck Scan Module
TTC	Transportation Technology Center
TTCI	Transportation Technology Center, Incorporated