Evaluation of Manual Infrared Brake Screening Technologies

Report Number: KTC-22-06/RSF19-71-1F

DOI: https://doi.org/10.13023/ktc.rr.2022.06

Kentucky Transportation Center
College of Engineering, University of Kentucky, Lexington, Kentucky

in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

The Kentucky Transportation Center is committed to a policy of providing equal opportunities for al persons in recruitment, appointment, promotion, payment, training, and other employment and education practices without regard for economic, or social status and will not discriminate on the basis of race, color, ethnic origin, national origin, creed, religion, political belief, sex, sexual orientation, marital status or age.

Kentucky Transportation Center
College of Engineering, University of Kentucky, Lexington, Kentucky

in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

KENTUCKY Transporation Center

Kentucky Transportation Center • University of Kentucky
176 Raymond Building • Lexington, KY 40506 • 859.257.6898 • www.ktc.uky.edu

University of Kentucky

Research Report
KTC-22-06/RSF19-71-1F

Evaluation of Manual Infrared Brake Screening Technologies

Joseph D. Crabtree, PhD., P.E.
Research Engineer

Brian Beaven
Research Scientist

and

Jennifer Walton, P.E.
Program Manager

Kentucky Transportation Center
College of Engineering
University of Kentucky
Lexington, Kentucky

In Cooperation With
Kentucky Transportation Cabinet
Commonwealth of Kentucky

April 2022

1. Report No. KTC-22-06/RSF19-71-1F	**2. Government Accession No.**	**3. Recipient's Catalog No**
4. Title and Subtitle Evaluation of Manual Infrared Brake Screening Technologies		**5. Report Date** April 2022 **6. Performing Organization Code**
7. Author(s): Joseph Crabtree, Brian Beaven, and Jennifer Walton		**8. Performing Organization Report No.** KTC-22-06/RSF19-71-1F
9. Performing Organization Name and Address Kentucky Transportation Center College of Engineering University of Kentucky Lexington, KY 40506-0281		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** RSF 19-71
12. Sponsoring Agency Name and Address Kentucky Transportation Cabinet State Office Building Frankfort, KY 40622		**13. Type of Report and Period Covered** **14. Sponsoring Agency Code**
15. Supplementary Notes Prepared in cooperation with the Kentucky Transportation Cabinet		

16. Abstract

The purpose of this project was to install and operate two manual infrared (IR) brake screening systems at Kentucky inspection facilities to enhance the quality of Level 1 safety inspections. A radio button in the inspection software allowed enforcement personnel to indicate when the IR equipment was used to select a truck for inspection. This feature allowed a direct comparison of performance measures (e.g., number of violations identified per inspection, out-of-service rate, etc.) for IR-generated inspections versus all inspections.

The evaluation focused on inspections at the Lyon County site for a 60-day period during September and October 2021. Analysis of the data showed that use of the IR technology to select trucks for inspection resulted in a substantially higher number of violations detected, a substantially higher out-of-service rate, and increased efficiency of enforcement personnel (in terms of violations found per inspection performed. The technology also appeared to be well accepted and appreciated by enforcement personnel, who regarded it as a beneficial addition to their toolkit.

17. Key Words truck, enforcement, commercial vehicle, weigh station, inspection		**18. Distribution Statement** Unlimited with approval of the Kentucky Transportation Cabinet	
19. Security Classification (report) Unclassified	**20. Security Classification (this page)** Unclassified	**21. No. of Pages** 12	**19. Security Classification (report)**

Table of Contents

List of Figures

List of Tables

Executive Summary

Every day, thousands of commercial motor vehicles pass through Kentucky, and only a small percentage of these vehicles can be screened, much less inspected, by enforcement personnel. It is essential that enforcement personnel have the best available tools and technologies to assist them in selecting trucks for inspection so that limited enforcement resources can be focused on those carriers and vehicles most likely to be in violation of applicable laws and regulations.

One of the more useful tools available for screening trucks for safety issues is infrared (IR) camera technology. This technology allows enforcement personnel to use visual indicators to identify trucks with apparent brake or tire deficiencies. Kentucky has been using IR technology for approximately 20 years.

The purpose of the current project was to install and operate two manual brake screening systems at Kentucky inspection facilities to enhance the quality of Level 1 safety inspections and thereby improve commercial vehicle safety. The two sites selected for this project were eastbound Lyon County (on I-24 in western Kentucky) and Rowan County (on westbound I-64 in eastern Kentucky). Supply chain issues delayed the installation of the equipment until shortly before the project end date, which limited the amount of time and data available for evaluating the systems. The Rowan County site lacked sufficient data for a meaningful evaluation, so the data analysis focused on Lyon County. Prior to the system installation, a radio button was added to the inspection software to allow enforcement personnel to indicate when a truck was chosen for inspection based on visual indicators from the IR technology. This allowed a direct comparison of performance measures (e.g., number of violations identified per inspection, out-of-service rate, etc.) for IR-generated inspections versus all inspections.

The evaluation focused on inspections at the Lyon County site for a 60-day period in September and October 2021. Analysis of the data showed that use of the IR technology to select trucks for inspection resulted in a substantially higher number of violations detected, a substantially higher out-of-service rate, and increased efficiency of enforcement personnel (in terms of violations found per inspection performed. The technology also appeared to be well accepted and appreciated by enforcement personnel, who regarded it as a beneficial addition to their toolkit.

It should be recognized that these conclusions are based on an analysis of limited data and could represent a “honeymoon” period for the technology. Additional data should be collected and analyzed to determine if the system continues to be used and continues to generate the benefits identified in this evaluation. Periodic refresher training may also help ensure that enforcement personnel are using the system to its maximum capabilities.

If further analysis indicates that the technology produces ongoing benefits, strong consideration should be given to installing this technology at additional sites, with the eventual goal of making it available at all fixed enforcement locations.

Chapter 1 Introduction

Background and Purpose

According to the Federal Motor Carrier Safety Administration (FMCSA), 5,237 large trucks and buses were involved in 4,696 fatal crashes in 2019. The number of fatal crashes involving large trucks and buses increased by 47 percent from 2009 to 2019. During that same time, injury crashes involving large trucks and buses more than doubled, from 60,000 to 127,000.[1] These numbers point to the enormous challenges facing federal and state agencies that are responsible for improving roadway safety through enforcement of motor carrier safety laws and regulations.

Every day, thousands of commercial motor vehicles, including trucks and buses, pass through Kentucky. Law enforcement agencies are saddled with stagnant if not declining operating budgets. In Kentucky, as in most states, only a small percentage of commercial vehicle traffic can be screened, much less inspected. Thus, it is essential that enforcement personnel have the best available tools and technologies to assist them in selecting trucks for inspection, so that limited enforcement resources can be focused on those carriers and vehicles most likely to be in violation of applicable laws and regulations.

One of the more useful tools available for screening trucks for safety issues is infrared (IR) camera technology. This technology allows enforcement personnel to use visual indicators to identify trucks with apparent brake or tire deficiencies. Kentucky has been using IR technology for approximately 20 years. Early deployments of this technology involved mobile vans with onboard cameras, computers, and monitors. The first fixed installations of IR technology at Kentucky weigh stations were at northbound Laurel County, Kenton County (southbound), and Simpson County (northbound) in 2005 and 2006. That technology was installed as part of a comprehensive screening system known as the Integrated Safety and Security Enforcement System (ISSES).

The purpose of the current project was to install and operate two manual brake screening systems at Kentucky inspection facilities to enhance the quality of Level 1 safety inspections and thereby improve commercial vehicle safety. This project was also intended to enhance the efficiency of enforcement by providing a tool to quickly identify commercial vehicle safety problems. The two sites selected for this project were eastbound Lyon County (on I-24 in western Kentucky) and Rowan County (on westbound I-64 in eastern Kentucky).

The original timeline for this project called for the technology to be installed at both sites in May of 2021. Unfortunately, due to supply chain issues, the Lyon County system was not installed until August 30, 2021, and the Rowan County system was installed in late September. With a project end date of September 30, this substantially shortened the available time for evaluation of actual system operations.

Chapter 2 Objectives and Methodology

Project Objective

The objective of this project, according to the work plan, was to "increase the number of brake and tire-related violations identified through inspection and thereby improve safety on Kentucky's roadways." The work plan further stated, "The identification of these violations should lead to an increase in the vehicle out-of-service rates at the chosen facilities."

System Description

The technology for this project was manufactured and supplied by Teledyne FLIR LLC and was installed by Kentucky Transportation Center personnel, with assistance from an I.T. support contractor. The system consists of the following major components:

Outside Components:

- FLIR Ranger MS-UC DefendIR™ 640 camera
- Traffic cabinet
- Electrical power to cabinet
- Fiber optic lines from building to cabinet
- Fiber optic converters
- Power conditioner

Inside Components:

- DefendIR™ joystick controller
- Cables
- Computer monitor
- Fiber optic converters

To use the system, an enforcement professional sits at the counter inside the weigh station building and watches the computer monitor as trucks roll past the camera. The joystick can be used to adjust the camera angle and zoom level or to follow a given truck as it moves along the ramp. Enforcement personnel look for anomalies in the heat signature from the truck's wheels and tires, which can indicate a non-functioning brake, an improperly inflated tire, or some other abnormality. Initial training is beneficial in learning how to operate the system controls and what clues to look for in spotting different types of problems. As operators gain experience in using the system, they tend to become increasingly proficient in operating the system and knowing what to look for.

As enforcement personnel gain proficiency with the system, some may choose not to sit at the counter but instead to keep an eye on the monitor as they go about their other duties. In this mode, the infrared system provides another visual clue that enforcement personnel can use when selecting trucks for inspection.

Figure 2.1 shows the external equipment installation at eastbound Lyon County.

Figure 2.1 Lyon County Installation

Evaluation Methodology

Starting at a very high level, the evaluation was focused on answering the following questions:

- Did the installation of these systems enhance the quality of Level 1 safety inspections at the selected facilities?
- Did the installation of these systems improve commercial vehicle safety?
- Did the installation of these systems enhance the efficiency of enforcement?
- Did the installation of these systems provide a tool to quickly identify commercial vehicle safety problems?

Since these questions include broad indicators that are difficult to directly measure (e.g., enhance quality, improve safety), it was necessary to drill down a bit to develop questions that are more directly measurable. For example, we could ask if the installation of these systems impacted any of the following measures:

- The number of brake-related and tire-related violations identified through inspection;
- The vehicle out-of-service rate;
- The total number of violations identified through inspection; and
- The total out-of-service rate.

In an ideal world, the installation and use of this technology would have a statistically significant impact on some (if not all) of these measures for the station as a whole. However, since only a fraction of the trucks selected for inspection would be selected using this technology, it was necessary to differentiate IR technology inspections from other inspections. This differentiation allows direct comparison of this technology to other methods of selecting trucks for inspection. This was accomplished by adding a “radio button” to the inspection software so that enforcement personnel could indicate any inspection for which the truck was selected using the IR technology.

A secondary objective of the evaluation was to answer questions about how consistently and reliably the technology works, how much it is used by the enforcement personnel, how efficient it is in identifying trucks for inspection, and the enforcement personnel's perceptions of the technology. This was not specifically addressed in the work plan, so these elements were considered desirable but not essential.

When the IR technology was installed at the Lyon County site, a trainer was brought in from another facility (where the technology has been in use for some time) to train the enforcement personnel on use of the system. Researchers from the Kentucky Transportation Center attended this training in order to observe the system in operation and ask questions of the trainer and trainees. The researchers also stressed the importance of using the aforementioned radio button to indicate which inspections were generated through use of the IR technology.

Due to the late date of the equipment installation at Rowan County (just days before the project end date), no formal training was provided for the enforcement personnel at that site.

To compare the technology with other methods of selecting trucks for inspection, researchers requested specific data (see the bulleted list below) from Kentucky's inspection database. Information was requested for Lyon County, for Rowan County, and for the two stations combined. Each data element was requested for all inspections and for IR-generated inspections:

- Number of inspections
- Number of inspections with one or more violations
- Total number of violations
- Number of inspections with one or more out-of-service (OOS) violations
- Total number of OOS violations
- Number of inspections with one or more brake-related violations
- Total number of brake-related violations
- Total number of OOS brake-related violations
- Number of inspections with one or more tire-related violations
- Total number of tire-related violations
- Total number of OOS tire-related violations

Data was requested for September 1 through October 30 of 2021.

Chapter 3 Findings and Analysis

Quantitative Analysis of Inspection Data

During the evaluation period of September 1 through October 30, there were 1,234 inspections conducted at eastbound Lyon County and Rowan County. Of these, 801 were conducted at Rowan County and 433 were conducted at eastbound Lyon County. There were a total of 25 inspections coded as IR-generated, with all but two of these occurring at Lyon County. The low number of IR-generated inspections at Rowan County can be attributed to the lack of formal training at that site, coupled with the coinciding installation of a tire pressure detection system that generated a high level of interest among the enforcement personnel at that site.

Due to the lack of IR-generated inspections at Rowan County (only 2 out of 801 total inspections), the evaluators decided to focus their analysis on Lyon County. The Lyon County data is presented in Table 3.1.

Table 3.1 Lyon County IR Inspection Data

Data Element	For "IR" inspections	For All Inspections
Number of inspections	23	433
Number of inspections with one or more violations	22	294
Total number of violations	74	736
Number of inspections with one or more OOS violations	17	178
Total number of OOS violations	25	223
Number of inspections with one or more brake-related violations	13	127
Total number of brake-related violations	42	296
Total Number of OOS brake-related violations	11	60
Number of inspections with one or more tire-related violations	9	99
Total number of tire-related violations	11	105
Total Number of OOS tire-related violations	10	104

These data elements were used to produce the following statistics, shown in Table 3.2.

Table 3.2 Statistical Analysis of Lyon County Data

Statistic	For "IR" Inspections	For All Inspections
Percentage of inspections with one or more violation	95.7%	67.9%
Average number of violations per inspection	3.22	1.70
Percentage of inspections with one or more OOS violations	73.9%	41.1%
Average number of OOS violations per inspection	1.09	0.52
Percentage of inspections with one or more brake-related violations	56.5%	29.3%
Average number of brake-related violations per inspection	1.83	0.68
Average number of OOS brake-related violations per inspection	0.48	0.14
Percentage of inspections with one or more tire-related violations	39.1%	22.8%
Average number of tire-related violations per inspection	0.48	0.24
Average number of OOS tire-related violations per inspection	0.43	0.24

Recognizing the relatively small sample size (only 23 "IR" inspections), it is important to avoid drawing broad conclusions from these statistics. Nevertheless, these initial results provide a strong indication of the potential value of the technology. These statistics are indicators of the effectiveness of roadside inspections, and every indicator showed the "IR" inspections to be dramatically more effective. For example:

- Nearly 100% of the "IR" inspections identified a violation, with more than three violations discovered per inspection.

- The OOS rate for the "IR" inspections was 74%, compared to 41% for all inspections.

- Brake violations were found at a much higher rate for the "IR" inspections, with more than three times as many OOS brake violations discovered per inspection.

- Tire violations were also found much more frequently, with twice as many violations per inspection.

Qualitative Assessment

Discussions with enforcement personnel during and after the system training provided some valuable insights about the system. Specific observations from those discussions included:

- The inspectors said we need to have this technology at ALL sites so that everyone gains experience with the systems and knows how to use them.

- When we asked the personnel if this technology was useful to them, i.e., helped them to do their jobs more effectively, they all said "definitely." They said it was "money well spent." They like being able to select trucks for inspection based on visual indication of a safety problem (as opposed to, for example, some sort of credentials flag from another system).

- The enforcement personnel stated they believe that anyone can learn to use this system. They provided an example of one employee who is colorblind and has learned to use it effectively.

- The best method for learning to use the IR system is to first work alongside someone who already knows the system and then to progress to using it alone. Improvement comes through experience and through trial and error.

- There are some trucks that are more difficult to screen using this technology. Trucks with disk brakes are challenging, since they don't generate as much heat. Empty trailers can be challenging for the same reason.

- Lower speeds help – trucks are on-screen longer, and it's easier to pan along with them. At lower speeds, there is more time to react and pull them in if needed. Longer ramps help for similar reasons.

- There are some issues with using the system in the rain. It still works OK, but the rain can dissipate some of the heat, or it can create streaks of hot water running down the tires (so you think there's a problem when there isn't).

- The prevailing way to use the system was just to set it up at a good orientation and then keep an eye on it as the trucks roll past it. If you see a truck of interest, you can sit down and pan to see more of it (if it's moving slowly enough and you are quick enough).

During and after the training session, researchers sat down at the system and practiced using it, with instruction from the trainers and other enforcement personnel. That experience generated additional observations, listed here:

- One researcher observed some issues with trying to find the "sweet spot," i.e., the best combination of distance, zoom, and orientation.

- If you can find the right spot, you can get a pretty good look at the truck without having to pan. However, you really need to pan (i.e., follow the truck with the joystick) in order to see everything you need to see.

- Each individual user will want to set it up for his/her preferences.

- With the Lyon County setup, one evaluator found himself wanting to zoom out further than the system would allow. Even zoomed all the way out, the truck would fill up the whole screen, and it would move across the screen very quickly. The evaluator questioned whether this can be changed in the camera settings, or if the installation is perhaps too close to the ramp.

- The auto-focus was not working at the time of the training, and this made it challenging to zoom in and out. Every time the operator changed the zoom, it went out of focus and had to be manually focused. And (at the time of the training), you couldn't focus it using the joystick controls; you had to make these adjustments using a separate computer. This was a hindrance to smooth and efficient use of the technology.

Chapter 4 Conclusions and Recommendations

Conclusions

Analysis of two months of inspection data from the eastbound Lyon County weigh station showed that use of the IR technology to select trucks for inspection resulted in a substantially higher number of violations detected, a substantially higher out-of-service rate, and increased efficiency of enforcement personnel (in terms of violations found per inspection performed). We can therefore conclude that the technology is extremely effective as a screening tool.

The technology also appears to be well accepted and appreciated by enforcement personnel. Despite the normal human tendency to resist change, enforcement personnel regarded this system as a beneficial addition to their toolkit.

Recommendations

It should be recognized that the conclusions stated above are based on an analysis of limited data and could represent a "honeymoon" period for the technology. Additional data should be collected and analyzed to determine if the system continues to be used and continues to generate the benefits identified in this evaluation. Periodic refresher training may also be in order to ensure that enforcement personnel are using the system to its maximum capabilities.

If further analysis indicates that the technology produces ongoing benefits, strong consideration should be given to installing this technology at additional sites, with the eventual goal of making it available at all fixed enforcement locations.

[1] Federal Motor Carrier Safety Administration; "Large Truck and Bus Crash Facts 2019"; https://www.fmcsa.dot.gov/safety/data-and-statistics/large-truck-and-bus-crash-facts-2019