Evaluation of Manual Thermal Brake Screening Systems

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

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Research Report
KTC-25-07

Evaluation of Manual Thermal Brake Screening Systems

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16. Abstract

In 2021, manual thermal brake screening systems were installed at Lyon EB and Rowan County weigh stations. Two additional units were installed at Laurel SB and Scott County weigh stations the following year. Although this system is called a thermal brake screening system, its thermal camera images are used to find both brake and tire-related violations. At the time of this project, Lyon (EB), Rowan, and Scott County inspection locations also had tire pressure detection systems in addition to manual thermal brake screening systems. Both systems can be used to identify tire-related violations, but inspectors prefer to use the tire pressure detection system for its ease of use. As a result, the usage rates for the thermal brake screening systems in Rowan and Scott Counties have been low to nonexistent. A quantitative analysis was conducted on the inspections that occurred at Lyon EB and Laurel SB, where the use of the technology was high, to determine the system's effectiveness. A comparison of the level 1 inspection results using the thermal brake screening system to the ones without thermal screening has shown that the system is effective in identifying vehicles with brake and tire-related violations. The use of thermal camera images resulted in a significantly higher number of detected violations and out-of-service placements. It should be noted that inspectors prefer to use tire pressure detection systems for tire-related violations over thermal camera images if an inspection location is already equipped with tire pressure detection systems. Additional training on thermal brake screening systems is recommended so inspectors can use the right tool for brake-violation identification. The training is recommended at weigh stations with both thermal brake screening systems and tire pressure detection systems. In considering expanded use of the thermal brake screening system, we recommend that Kentucky explore the benefits and costs associated with automated systems as an alternative to the manual ones. A quantitative comparison of benefits and costs of an automated system is currently unavailable, so we recommend Kentucky 1) reach out to states with automated systems and collect information on the frequency of breakdowns, the main causes of the breakdowns, the duration of the breakdowns before repair, and the costs related to the repairs; 2) compare them to manual systems in Kentucky; and 3) conduct a cost-benefit analysis to examine if the benefits outweigh the costs. If the analysis determines that the expected benefits outweigh the foreseen costs, we recommend Kentucky install one automated thermal imaging system at a weigh station for an in-depth evaluation of the system's effectiveness before deciding upon further expansion.

17. Key Words thermal brake screening systems, infrared cameras, infrared detectors, commercial vehicles, weigh stations, brakes		**18. Distribution Statement** Unlimited with approval of the Kentucky Transportation Cabinet	
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Executive Summary

Kentucky State Police - Commercial Vehicle Enforcement (KSP-CVE) officers and inspectors conduct thorough inspections at weigh stations and the roadside to identify commercial vehicles with safety issues and remove them from public roadways. A large volume of trucks operate daily on highways in Kentucky, so inspecting every vehicle entering weigh stations is not feasible or ideal. With the limited number of enforcement personnel available for high-level inspections, selecting a truck with vehicle safety violations during the prescreening process is difficult. Weigh stations in Kentucky have been equipped with technologies and databases that help inspectors decide which vehicles need to be directed to park for further inspections. This report focuses on manual thermal brake systems and their effectiveness in identifying brake and tire-related violations. Kentucky has been using this technology for approximately 20 years. For this project, four weigh stations were equipped with the system.

In 2021, manual thermal brake screening systems were installed at Lyon (EB) and Rowan County. Two additional units were installed at Laurel (SB) and Scott County the following year. Formal training on the system operation was provided immediately after the installation at Lyon EB, which positively impacted the frequent usage of the newly installed system. However, delayed training at the Rowan inspection site and the installation of another technology with overlapping functions hindered the adoption of the manual thermal brake screening system. There was no record of the use of the system at Rowan County since the installation.

Even though the system is called a thermal brake screening system, the thermal camera images are used to find both brake and tire-related violations. Several inspection locations in Kentucky have both thermal brake screening systems and tire pressure detection systems. The issue is that these two systems have an overlapping function: detecting tire-related violations. However, while tire pressure detection systems automatically flag vehicles with a potential safety issue, the thermal brake screening system requires an inspector to review the image on a computer screen and actively look for the heat signatures related to faulty brakes and tires. Because of the ease of use, inspectors prefer tire pressure detection systems to identify tire-related violations when both technologies are available. Future training on thermal brake screening systems should focus on finding faulty brakes so inspectors can use the right tool for brake-violation identification, leaving tire-violation detection to tire pressure detection systems.

The Lyon EB and Laurel SB inspection locations showed frequent use of thermal camera imagery after installation. The data on inspections and the violations were extracted from Kentucky's inspection database and analyzed to examine the system's effectiveness. By comparing level 1 inspections performed with the system to inspections without it, the system demonstrates effectiveness in identifying vehicles with brake and tire-related violations. The use of thermal camera images resulted in a significantly higher number of violations detected and out-of-service placements ordered. Implementing timely training while inspectors were motivated by a high level of interest in the newly installed technology resulted in frequent use, which positively impacted inspection results.

In considering expanded use of the thermal brake screening system, we recommend that Kentucky explore the benefits and costs associated with automated thermal imaging systems as an alternative to the manual ones. An automated system analyzes the captured image as a vehicle passes a thermal camera by comparing the recorded patterns on the thermal image to the predefined conditions. Then, it alerts inspectors if any malfunctioning brakes are detected. The entire process is automated, which requires only minimal input from inspectors. The expected benefit from the automated system is sizeable, but it comes with caveats, including significantly high installation and maintenance costs. Also, through previous correspondence with enforcement personnel in other states using these automated systems, we have learned about their frequent breakdowns and high maintenance costs. Therefore, we

recommend Kentucky 1) reach out to states with automated systems and collect accurate information on the frequency of breakdowns, the main causes of the breakdowns, the duration of the breakdowns before repair, and the costs related to the repairs; 2) compare them to manual systems in Kentucky; and 3) conduct a cost-benefit analysis to examine if the expected benefits (e.g., increased usage, consistent effectiveness, decreased input from inspectors, etc.) outweigh the costs (e.g., higher system installation cost, higher annual maintenance cost, decreased usage during the repair, etc.). If the analysis determines that the expected benefits outweigh the foreseen costs, we recommend Kentucky install one automated thermal imaging system at a weigh station for an in-depth evaluation of the system's effectiveness before deciding upon further expansion.

Chapter 1 Introduction

1.1 Background

In 2020, 4,998 large trucks and buses were involved in fatal crashes - a 5% decrease from 20191. It could be deemed an accomplishment achieved through the prolonged effort of the trucking industry, federal and state governments, and safety organizations in making public roadways safer. The slight decrease in fatal crashes involving trucks and buses is noteworthy, as the overall fatal crashes increased from 2019 to 2020 by 6.8%2. In order to further reduce fatal crashes involving trucks, effective enforcement to keep unsafe trucks off public highways is crucial, as well as a voluntary effort by motor carriers to maintain vehicles up to safety standards.

Kentucky has fourteen fixed and three virtual weigh stations for commercial vehicles to pass through for various levels of inspections. However, only a small subset of the vehicles are directed to park for inspections by Kentucky State Police - Commercial Vehicle Enforcement (KSP-CVE) officers and inspectors. With the limited personnel available for high-level inspections and inadequate physical space to perform them, effective prescreening technologies for selecting high-risk vehicles for inspections are crucial for better safety outcomes. Since the first installations in 2005 and 2006 in Laurel (NB), Kenton (SB), and Simpson (NB) County in Kentucky, thermal camera images have been used to detect brake and tire-related issues as vehicles enter a weigh station.

1.2 Purpose

Recently, manual thermal brake screening systems were installed at four weigh stations in Kentucky to improve enforcement efficiency. The systems provide an additional tool for inspectors to quickly identify brake and tire-related issues on a vehicle as it enters the weigh station. The systems were installed and became fully functional in August and November 2021 at Lyon (EB) and Rowan County, respectively. In 2022, systems were installed and integrated into existing screening systems at Scott and Laurel (SB) County weigh stations in June and August, respectively. Following the installation, inspectors with ample experience with the system provided training sessions. During the two-hour training sessions, a proficient trainer and a Kentucky Transportation Center employee explained the overall configuration of the system, showed how to use a joystick controller to follow a truck, and pointed out what to look for on the monitor to detect brake and tire-related issues. Participants had opportunities to try out the system and ask technical questions to the trainer during the training sessions.

The manual thermal brake screening systems were installed to increase the number of brake and tire-related violations identified through inspections and thereby improve safety on Kentucky's roadways. To measure the magnitude of its impact on detecting vehicle safety violations of interest, KTC researchers analyzed inspections and the violations found at the four weigh stations. The time period of the study was from a month after the training ended to the end of 2022.

[1] Federal Motor Carrier Safety Administration. (2022, October). Large Truck and Bus Crash Facts 2020. https://www.fmcsa.dot.gov/safety/data-and-statistics/large-truck-and-bus-crash-facts-2020#A1

[2] National Center for Statistics and Analysis. (2022, September). Summary of motor vehicle crashes: 2020 Data. (Traffic Safety Facts. Report No. DOT HS 813 369). National Highway Traffic Safety Administration.

Chapter 2 Objectives and Methodology

2.1 Objectives

The project's objective is to install additional manual thermal brake screening systems at fixed weigh stations in Kentucky to provide an extra tool for KSP-CVE officers and inspectors to identify more brake and tire-related violations during inspections. Identifying these violations will result in more vehicle-out-of-service rates, playing a critical role in keeping unsafe vehicles off Kentucky's roadways. The project's work plan includes the four performance objectives below.

- Identify the locations and select a vendor to supply the thermal brake screening systems for fixed inspection stations in Kentucky.
- Install two manual thermal brake screening systems at fixed inspection stations in Kentucky.
- Train enforcement personnel in the effective use of the system.
- Evaluate long-term safety impacts offered by the new system by analyzing inspection performance, vehicle out-of-service rates, and safety violations found.

This report focuses on the last listed objective, providing a quantitative analysis of the system's effect on safety outcomes. Analysis was performed using the inspection data and violations identified during the inspections.

2.2 Manual Thermal Brake Screening System Installation and Training

This report focuses on the performance of the newly installed systems and their usage at the four weigh stations. Table 2.1 shows each weigh station's installation and training dates. The training was provided at Lyon EB a week after the system installation, but the training for Rowan County weigh station was delayed due to scheduling difficulties. An experienced trainer traveled to Laurel County for training on September 6, 2022, and provided training at the Rowan County weigh station the following day.

Table 2.1 Installation and Training Dates

Location	Installation	Training
Lyon EB	8/23/2021	9/1/2021
Rowan	11/17/2021	9/7/2022
Scott	6/14/2022	9/6/2022*
Laurel SB	8/8/2022	9/6/2022

* KSP-CVE officers and inspectors from Scott and Laurel County participated in the Central region training at Laurel SB.

2.3 Manual Thermal Brake Screening System Usage

In order to use the system, enforcement personnel must sit in front of a monitor with a joystick and watch/adjust the computer screen to detect anomalies affecting the brakes and tires of a vehicle on the weigh station ramp. As an inspector gains more experience operating the system and accumulates knowledge on the specific heat signatures on a vehicle's wheels and tires when a vehicle operates with a faulty brake and/or flat tire, the response time becomes shorter and the accuracy improves. An experienced inspector emphasized that it usually takes 2-3 weeks for an inspector without previous experience to quickly detect brake and tire-related issues.

Due to the time and effort required to be proficient in using the system and having to sit in front of the computer monitor to take advantage of the system, its effectiveness heavily depends on the enforcement professionals at each

weigh station. Figure 2.1 shows the usage rate at weigh stations since the installation. Among the four weigh stations, Lyon (EB) and Laurel (SB) County inspectors used the thermal camera images to screen vehicles for level 1 inspection at a meaningful rate. However, Scott County did not report the use of the system often, and Rowan County did not report its use at all since installation.

The manual thermal brake screening systems were installed in 2021 at Lyon and Rowan County weigh stations. After installation, a training session was provided to inspectors at Lyon County, but not at Rowan County due to the scheduling difficulties. In June 2022, 112 level 1 inspections were conducted at Lyon County. Among them, 34 vehicles were inspected after an inspector found brake or tire-related issues on the thermal camera images (30.36%). However, Rowan County inspectors did not take advantage of the new system due to a lack of proper training. Therefore, the usage rate for thermal camera images has been zero at Rowan County since the installation. Another contributing factor for the low usage rate at Rowan County is the availability of a tire pressure detection system at the weigh station. While the thermal brake screening system requires inspectors to look at the images to determine potential issues, the tire pressure detection system automatically identifies the tires with safety issues. As Rowan County inspectors gained access to two new tools to detect tire-related safety issues in November 2021, it is understandable that inspectors preferred using the tool that automatically detects a potential problem.

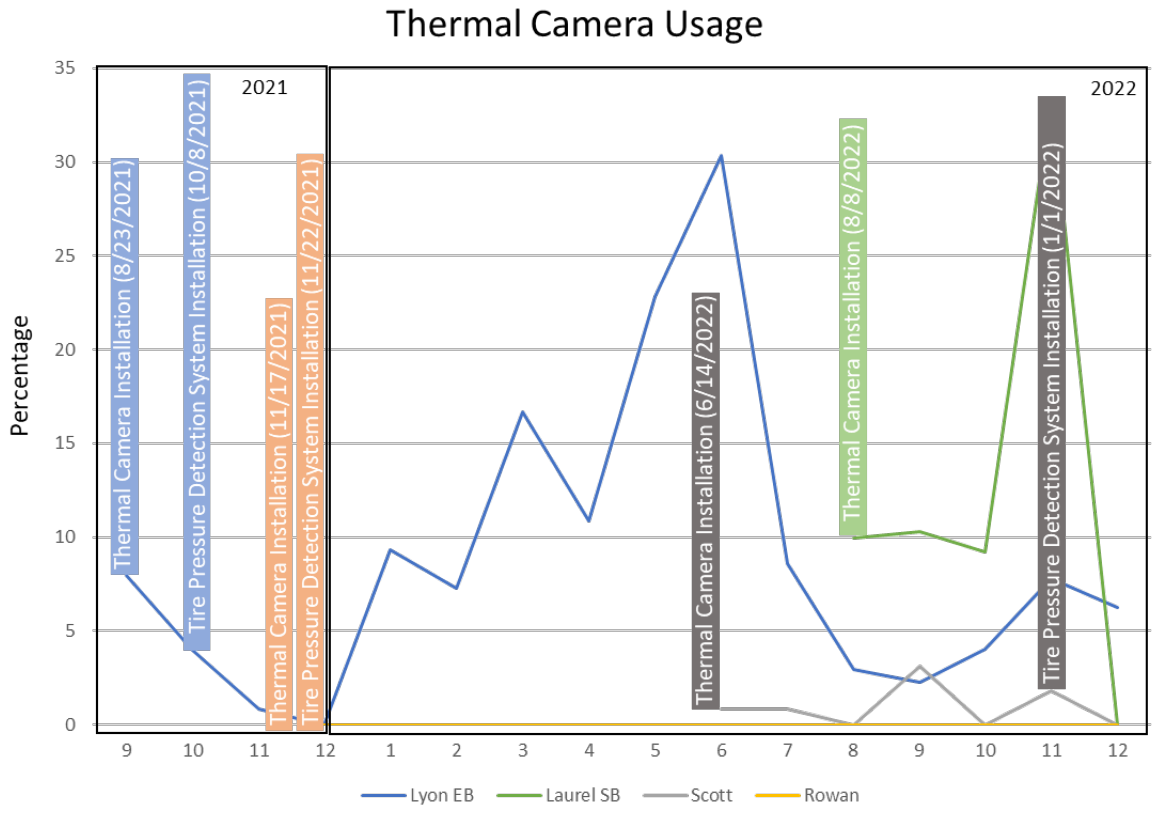

Figure 2.1 Thermal Camera Usage Rate for Level 1 Inspections

The system was installed at Laurel County (SB) in August 2022, and training was provided the following month. As mentioned by a trainer, it took a while for inspectors to gain proficiency, and the usage significantly increased in November. Over thirty% of the level 1 inspections used thermal camera images in the prescreening process. The sudden decrease in the usage in December may need to be excluded as there was only one level 1 inspection in

December, which may affect the significance of the usage rate in the month. Laurel County (SB) did not have a tire pressure detection system during the evaluation period, leaving inspectors to rely heavily on thermal camera images to identify tire-related issues. Scott County shows similar usage patterns to Rowan County. The usage rate has never been significant since the installation, and the availability of the tire pressure detection system at the station would not help inspectors to use thermal camera images over the tire pressure detection system for tire-related issues.

2.4 Evaluation Methodology

Researchers performed a quantitative analysis to determine if the thermal brake screening systems installed at Kentucky weigh stations improved inspection efficiency. Using the level 1 inspection data from Lyon EB and Laurel SB weigh stations, the two stations with a significant usage history of the system, we posed the following questions.

- Did the enforcement personnel identify more *brake-related violations* with a manual thermal brake screening system?
- Did the enforcement personnel identify more *tire-related violations* with a manual thermal brake screening system?
- Did the enforcement personnel find more *violations (all)* with a manual thermal brake screening system?
- Did the enforcement personnel place more vehicles *out-of-service for brake safety violations* with a manual thermal brake system?
- Did the enforcement personnel place more vehicles *out-of-service for tire safety violations* with a manual thermal brake system?
- Did the enforcement personnel place more vehicles *out-of-service (all)* with a manual thermal brake system?

Inspectors recorded whether the system was used in selecting trucks for inspection when filing a report, distinguishing inspections that used the system from those that did not. Using the inspection data extracted from Kentucky's inspection dataset, we compared the outputs of the inspections with the system to those without the system. The specific inspection outputs of interest are:

- All violations, including both vehicle and driver safety violations
- Brake-related violations
- Tire-related violations
- All out-of-service, including both vehicle and driver out-of-service
- Out-of-service for brake-related violations
- Out-of-service for tire-related violations

Based on the performance evaluation of the system and its historical usage, recommendation for expanding use of the system at other weigh stations in Kentucky were made.

Chapter 3 Findings and Analysis

3.1 Overview of Level 1 Inspection Data

Due to the minimal use of thermal camera images at Scott and Rowan County, the analysis was conducted using level 1 inspection data from Lyon EB and Laurel SB weigh stations. Among eight levels of inspections that can occur, the most thorough and detailed one is a level 1 inspection[3]. An inspector performs a 37-step inspection of both carrier and driver, including verifying credentials, driving log, mechanical condition of the vehicle, and any hazardous materials present during the level 1 inspection[4]. As lower-level inspections are not designed to detect some brake-related violations, this analysis excluded them.

The data included inspections that occurred between a month after the formal training and the end of 2022. A formal training took place on September 1, 2021 at Lyon EB and on September 6, 2022 at Laurel SB. Therefore, we used the inspection data collected from October 1, 2021 to December 31, 2022 for Lyon EB and data collected from October 1, 2022 to December 31, 2022 for Laurel SB. An experienced and proficient user of the system estimated 2-3 weeks of trial and error before an inspector can gain proficiency with the system. Thus, the reasoning for the one month delay between the training and the beginning of the data collection.

There were 2,512 level 1 inspections at the Lyon EB weigh station from October 1, 2021 to December 31, 2022. Approximately 8% of them utilized thermal camera images during the prescreening process before an inspector decided to direct a vehicle into the parking area for level 1 inspection. Thermal cameras capture infrared light, so inspections that use thermal camera images are called "IR" inspections. Among the 208 "IR" inspections, 207 inspections resulted in one or more violations found. Specifically, 175 vehicles had at least one brake-related safety issue and inspectors found at least one tire-related issue on 202 vehicles.

The analysis also included inspections that occurred at Laurel SB weigh station for three months (October 1, 2022 – December 31, 2022). There were 225 level 1 inspections during that time, and over 11% of inspection records indicated the use of thermal camera images in prescreening. Among the 25 inspections performed after an inspector spotted faulty brakes or flat tires on the computer screen, 14 vehicles were recorded with one or more brake-related violations. In addition, inspectors placed an out-of-service designation for tire safety violations on three trucks.

Table 3.1 Description of Level 1 Inspection Data (October 1, 2021-December 31, 2022 at Lyon EB and October 1, 2022-December 31, 2022 at Laurel SB)

	Lyon EB		Laurel SB	
	For IR Inspections	For Non-IR Inspections	For IR Inspections	For Non-IR Inspections
Number of inspections	208	2,304	25	200
Number of inspections with one or more violations	207	1,724	16	94
Total number of violations	609	4,655	69	273
Number of inspections with one or more OOS violations	203	992	13	48
Total number of OOS violations	301	1,347	33	89

[3] Commercial Vehicle Safety Alliance. (2023). All Inspection Levels. https://www.cvsa.org/inspections/all-inspection-levels/

[4] Commercial Vehicle Safety Alliance. (2023). Understanding the North American Standard Inspection Program. https://www.cvsa.org/wp-content/uploads/NASI-Program-Brochure.pdf

	Lyon EB		Laurel SB	
	For IR Inspections	For Non-IR Inspections	For IR Inspections	For Non-IR Inspections
Number of inspections with one or more brake-related violations	175	959	14	54
Total number of brake-related violations	378	2,047	45	130
Total Number of OOS brake-related violations	201	620	20	57
Number of inspections with one or more tire-related violations	202	655	3	14
Total number of tire-related violations	225	703	3	16
Total Number of OOS tire-related violations	215	667	3	10

3.2 Quantitative Analysis of Inspection Data

Table 3.2 shows the effectiveness of the thermal brake screening system by comparing the average number of brake and tire-related violations found during the "IR" inspections and "Non-IR" inspections.

A detailed look at the inspections that took place at Lyon EB weigh station shows the following:

- 99.5% of the time, "IR" inspections resulted in one or more violations, while less than 75% of the "Non-IR" inspections showed the same result.
- The OOS rate for "IR" inspections was 97.6%, while it was 43.1% for "Non-IR" inspections.
- On average, inspectors found 1.82 brake-related violations during the "IR" inspections, while the average number of brake-rated violations was less than half during the "Non-IR" inspections.
- More tire violations were found during "IR" inspections compared to "Non-IR" inspections.

There was a similar pattern of "IR" inspections being more effective in identifying vehicles with potential violations than "Non-IR" inspections at the Laurel SB weigh station. The analysis of level 1 inspections at the Laurel SB weigh station shows the following:

- While less than half of "Non-IR" inspections resulted in one or more violations, 64% of the "IR" inspections found one or more violations.
- The OOS rate for "IR" inspections was significantly higher than "Non-IR" inspections (52% vs. 24%).
- The average number of brake-related violations during the "IR" inspections was 1.80. Inspectors found only a third of the violations during the "Non-IR" inspections.
- The percentages of inspections with tire-related violations detected were low, as only 12% of the "IR" and 7% of the "Non-IR" inspections resulted in any violations found.

Table 3.2 Comparison of Inspection Outcome ("IR" Inspections vs. "Non-IR" Inspections)

	Lyon EB		Laurel SB	
	For IR Inspections	For Non-IR Inspections	For IR Inspections	For Non-IR Inspections
Percentage of inspections with one or more violations	99.5%	74.8%	64.0%	47.0%
Average number of violations per inspection	2.93	2.02	2.76	1.37

	Lyon EB		Laurel SB	
	For IR Inspections	For Non-IR Inspections	For IR Inspections	For Non-IR Inspections
Percentage of inspections with one or more OOS violations	97.6%	43.1%	52.0%	24.0%
Average number of OOS violations per inspection	1.45	0.58	1.32	0.45
Percentage of inspections with one or more brake-related violations	84.1%	41.6%	56.0%	27.0%
Average number of brake-related violations per inspection	1.82	0.89	1.80	0.65
Average number of OOS brake-related violations per inspection	0.97	0.27	0.8	0.29
Percentage of inspections with one or more tire-related violations	97.1%	28.4%	12.0%	7.0%
Average number of tire-related violations per inspection	1.08	0.31	0.12	0.08
Average number of OOS tire-related violations per inspection	1.03	0.29	0.12	0.05

Overall, "IR" inspections resulted in inspections with more brake and tire-related violations identified, and more trucks placed in out-of-service at both weigh stations, showing the effectiveness of the thermal brake screening system if used during the screening process. The main focus of this report is to compare the results of "IR" inspections to "Non-IR" to determine the effectiveness of the thermal brake screening systems installed, but the side-by-side comparison of weigh station performance necessitates the explanation for sizeable differences between Lyon EB and Laurel SB weigh stations. For example, the average number of tire-related violations found during "IR" inspections was 1.08 at Lyon EB, while 0.12 violations were identified at Laurel SB. The large gap could be explained by differences in familiarity/experience with the technology and other equipment available at each weigh station. The higher experience level of inspectors at Lyon EB could be a factor contributing to a higher number of tire-related violations found during "IR" inspections, as inspectors at Lyon EB were introduced and encouraged to use the technology one year before the inspectors at Laurel SB. The other reason for the higher number of tire-related violation detections at Lyon EB could be the tire pressure detection system installed at the station, which was unavailable at Laurel SB at the time of evaluation. The combination of the two mentioned factors seems to significantly boost the tire-related violation detection at Lyon EB compared to Laurel SB. Further study using the inspection data after the tire pressure detection system installation at Laurel SB could be beneficial in explaining the significant differences between weigh stations.

Chapter 4 Conclusions and Recommendations

4.1 Conclusions

A comparison of "IR" inspection results to "Non-IR" showed that using the thermal brake screening system improved the overall quality of level 1 inspections. When an inspector used the technology to select a truck for a full inspection, it resulted in significantly more identified violations and out-of-service designations. With this tool, inspectors enhanced their performance by doubling the number of brake-related violations and tripling the detected tire-related violations. The analysis shows that thermal brake screening is a beneficial tool that prevents inspectors from passing trucks with potential safety issues which could pose threats to public safety on Kentucky roadways.

However, it should be noted that timely and well-focused training is essential in encouraging inspectors to use the newly installed technology. The usage rate of the system at fixed inspection locations varies significantly from 0% to over 30%. This system requires 2-3 weeks of trial and error for an inspector with no prior experience to be able to take advantage of the system at its full potential. Without training and a learning environment that allows inspectors to continue to try, inspectors tend to depend on other available screening devices and information.

It is worth mentioning that the length of experience with the technology positively impacts identifying a higher number of violations per "IR" inspection. Inspectors at Lyon EB have almost one year more experience with the thermal brake screening system compared to the inspectors at Laurel SB, as the system installation dates at Lyon EB and Laurel SB were almost one year apart. "IR" inspection outcomes, which were measured in terms of the number of violations detected and the out-of-service designations, are significantly higher at Lyon EB compared to Laurel SB. Longer experience with the thermal brake screening system combined with timely training offered immediately after the system installation are the two factors explaining the successful use of the thermal brake screening system.

4.2 Recommendations

The analysis concluded that the thermal brake screening system is an effective tool that an inspector can use during the commercial vehicle screening process. However, whether an inspector uses the system or not is a separate issue. It is a manual system that requires an inspector to look at the computer screen and actively look for a heat signature related to brake and tire-related violations. Inspectors expressed their hesitation to be fully invested in learning how to operate the system because of its lack of automation.

Along with the thermal brake screening system, Kentucky has expanded tire pressure detection systems at fixed inspection sites statewide. Their functions overlap, and a tire pressure detection system is more appealing to inspectors due to the minimal learning time and highly automatic mechanism. However, a thermal brake screening system is effective in identifying vehicles with potential brake-related problems, which cannot be detected with other technologies available at weigh stations. As some weigh stations already have both systems installed, additional training and discussion sessions focusing on brake-related violations may improve the frequency of use of the already installed system.

In considering expanded use of the thermal brake screening system, we recommend that Kentucky explore the benefits and costs associated with automated thermal imaging systems as an alternative to the manual ones that have been installed. An automated system analyzes the captured image as a vehicle passes a thermal camera by comparing the recorded patterns on the thermal image to the predefined conditions. Defective brakes are typically colder than adequately functioning brakes, and an automated system alerts inspectors if any malfunctioning brakes are detected using relevant temperature data. Unlike the manual system, which requires inspectors to review

thermal images as vehicles enter a weigh station and determine whether to stop the vehicle for inspection, the automated system does not require an active role unless the system gives an alert on faulty brakes. However, installing and maintaining an automated system costs significantly more than a manual system. Also, through previous correspondence with enforcement personnel in other states using these automated systems, we have learned about their frequent breakdowns and high maintenance costs. Therefore, we recommend Kentucky 1) reach out to states with automated systems and collect accurate information on the frequency of breakdowns, the main causes of the breakdowns, the duration of the breakdowns before repair, and the costs related to the repairs; 2) compare them to manual systems in Kentucky; and 3) conduct a cost-benefit analysis to examine if the expected benefits (e.g., increased usage, consistent effectiveness, decreased input from inspectors, etc.) outweigh the costs (e.g., higher system installation cost, higher annual maintenance cost, decreased usage during the repair, etc.). If the analysis determines that the expected benefits outweigh the foreseen costs, we recommend Kentucky install one automated thermal imaging system at a weigh station for an in-depth evaluation of the system's effectiveness before deciding upon further expansion.