U.S. Department
of Transportation

Federal Motor Carrier Safety
Administration

Evaluation of Infrared Brake Screening Technology: Final Report

DOT-MC-01-007 ***December 2000***

Technical Report Documentation Page

1. Report No. DOT-MC-01-007	**2. Government Accession No.** PB2001-100010	**3. Recipient's Catalog No.**
4. Title and Subtitle Evaluation of Infrared Brake Screening Technology: Final Report		**5. Report Date** December, 2000 **6. Performing Organization Code**
7. Author(s) Anne-Claire Christiaen and Steve J. Shaffer		**8. Performing Organization Report No.**
9. Performing Organization Name and Address Battelle Memorial Institute 505 King Avenue Columbus, OH 43201		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-96-C-00077
12. Sponsoring Agency Name and Address Federal Motor Carrier Safety Administration		**13. Type of Report and Period Covered** Final Report for Evaluation June 1, 1999 - May 31, 2000 **14. Sponsoring Agency Code**

15. Supplementary Notes
The work was originally carried out under the USDOT, Federal Highway Administration, Office of Motor Carriers. The current supporting organization is the Federal Motor Carrier Safety Administration (FMCSA).

16. Abstract

This report documents the results of a field evaluation of the InfraRed Inspection System (IRISystem). The objective of the evaluation was to determine the effectiveness of the IRISystem in enhancing the screening of commercial motor vehicles (CMVs) in real time at the roadside for problematic conditions, primarily malfunctioning brakes. Four states - Georgia, Kentucky, North Carolina and Tennessee - participated in the evaluation for one year.

CMVs were screened by IRISystem while in queue at scale sites and subsequently subjected to a CVSA Level 1 (L1) inspection. A limited number of vehicles with no apparent problematic conditions were also inspected as a control group for the study. Fifty-nine percent of the vehicles screened by the IRISystem as problematic were placed out of service (OOS) in the Level 1 inspection, mostly for brake violations (nearly 80%). The percentage of vehicles placed OOS after IRISystem screening (59%) exceeded the effectiveness criterion of 50% defined by the State of Kentucky in this program for the vehicle-by-vehicle analysis.

The percentage of CMVs placed out of service with brake problems increased by a factor of 2.5 after using the IRISystem to screen vehicles for inspection. Additional considerations (training requirements, set up requirements, advantages, and limitations) are also reported herein.

17. Key Words brakes, brake tester, brake testing, infrared, screening, inspection, commercial vehicle	**18. Distribution Statement** No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.		
19. Security Classic. (of this report) N/A	20 **Security Classic. (of this page)** N/A	**21. No. of Pages** Body: 34 Appendices: 54 Total: 88	**22. Price**

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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Abbreviations

3-S2	Combination vehicle including a 3-axle tractor and a 2-axle trailer
CFR	Code of Federal Regulations
CMV	Commercial Motor Vehicle
CVSA	Commercial Vehicle Safety Alliance
DOT	Department of Transportation
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	Federal Motor Carrier Safety Regulation
FMVSS	Federal Motor Vehicle Safety Standard
IRISystem	InfraRed Inspection System
L1	Level 1
MCSAP	Motor Carrier Safety Assistance Program
NHTSA	National Highway Traffic Safety Administration
OMCS	Office of Motor Carrier Safety
OOS	Out Of Service
PBBT	Performance-Based Brake Tester

Definitions

Blind vehicle	A vehicle selected for a Level 1 inspection even though the IRISystem did NOT identified potential problems.
Defective brake	A brake found to have a FMCSR defect by the Level 1 inspection or, A brake that can not meet a minimum torque output.
Defective vehicle	A vehicle for which the Level 1 inspection reported one or more violations to safety regulations.
False positive	*Wheel-by-wheel*: one or more defect(s) (FMCSR violation(s)) were found on a wheel previously judged normal by the IRISystem operator, *Vehicle-by-vehicle*: a vehicle judged as blind, non-problematic by the IRISystem operator was placed OOS during the level 1 inspection.
False negative	*Wheel-by-wheel*: no defect (or FMCSR violation) was found on a wheel previously judged problematic by the IRISystem operator, *Vehicle-by-vehicle*: a vehicle judged as problematic by the IRISystem operator was NOT placed OOS during the level 1 inspection.
Normal brake	A brake, which according to the IRISystem operator, does not appear hotter or colder than the other brakes on the vehicle.
OOS vehicle	A vehicle for which FMCSR defect(s) meet one or more CVSA-defined out-of-service criteria, (i.e. the vehicle presents an imminent hazard).
Problematic brake	A brake, which according to the IRISystem operator, appears significantly colder or hotter than the other brakes on the vehicle.
Problematic vehicle	A vehicle selected for a Level 1 inspection and for which the IRISystem identified one or more potential problems.

Acknowledgments

This work was supported by the US DOT, Federal Highway Administration - Office of Motor Carrier and Highway Safety, under contract DTFH61-96-C-00077.

We would like to recognize the following states for their hard work and dedication. Without them, this research project could not have been completed.

Kentucky:	J. Bibb, Officers S. McCowan and T. Truesdale.
Georgia:	Captain D. Lively, Officers G. Davis, M. Grant, and J. L. Turner.
North Carolina:	Colonel D. C. Richards, Major C. J. Carden, Captain G. Gray, Sgt. R. Hines, Officers M. Byer and C. Frady.
Tennessee:	Major B. Lawson, Lt. C. Hopkins, Sgt. T. Hunt, Officers D. Drumwright, J. Harmon, M. Loftis, K. Norris, L. Skeen, R. White, and J. Wyatt.

Special thanks go to Katherine K. Hartman and Tom Marlow for their assistance in the project. We would also like to thank Wilf Wedding, of IRISystem, for dedicating time to the program, particularly for training the inspectors. The efforts and contributions of the task order manager, Robert Buz Schultz, are greatly appreciated.

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Introduction

The InfraRed Inspection System (IRISystem) was evaluated in a field study to determine the effectiveness of this new technology for enhancing the screening of commercial motor vehicles (CMVs) for subsequent inspection.

The IRISystem is housed in a mobile van and can be positioned in a roadside inspection facility where commercial motor vehicles are applying their brakes to enter the facility. The IRISystem camera creates an infrared image of the CMV showing the relative temperature of wheels on the vehicle as the operator tracks the vehicle with the camera controls. After the CMV's brakes have been applied, a functional brake appears bright white, indicating that it is "hot." A non-functioning brake appears dark, or "cold."

Scope and Objectives

The objective of the evaluation was to determine the effectiveness of the IRISystem in enhancing the screening of CMVs in real-time at the roadside. The IRISystem was evaluated as a means to:

- Detect problematic CMV conditions--mainly brake-related defects. The IRISystem results were compared directly with roadside inspection results (on a wheel-by-wheel and vehicle-by-vehicle basis) and,
- Improve the existing screening methods. The roadside inspection results obtained after IRISystem screening were compared with roadside inspection results obtained after current screening (SafetyNet data).

Description of the program

Four states participated in the evaluation over the course of one year: Kentucky, Georgia, North Carolina and Tennessee. In this project, CMVs were screened by the IRISystem operator, and subsequently subjected to a CVSA Level 1 (L1) inspection. The IRISystem was set up at selected locations where CMVs could be readily screened and inspected, primarily while at scale sites on highways.

Results

Summary of data collected

Nearly 400 CMVs were inspected following IRISystem screening by the four states in one year. To improve the objectivity of the study, 62 vehicles with no apparent problems ("blind" vehicles) according to the IRISystem operator were selected also for a Level 1 inspection. These blind, non-problematic vehicles (per IRISystem screening results) represented 16% of the total population of CMVs tested in the evaluation.

Approximately 10% of the wheels screened by the IRISystem (399 out of 3769) were identified as problematic and cold, and about 1% of the wheels screened by the IRISystem (44 out of 3769) were identified as problematic and hot.

Most of the problems identified during the IRISystem screening were located on the trailer wheels located on the far side of the CMV (with respect to the IRISystem van). Wheel covers on the near-side wheels tended to obscure the infrared image, whereas the far-side wheels were easier to evaluate because of a better line of sight to the back of the wheel and slightly more viewing time as the CMV passed in front of the IRISystem van. The presence of brake defects or deficiencies was a good indicator that other repairs were needed on the CMV.

Identification of Out-Of-Service CMVs (Vehicle-by-vehicle Analysis)

For all participating states, fifty-nine percent (194 out of 330) of vehicles screened by IRISystem as problematic were subsequently placed OOS in the Level 1 inspection. Seventy-nine percent (153 out of 194) of the screened OOS vehicles were placed OOS as a result of brake violations, among which 22% (42 out of 194) had brake and other OOS violations (for example, driver related violations). The percentage of blind, non-problematic vehicles placed OOS (false negatives) was 19% (12 out of 62).

The effectiveness criterion defined by Kentucky was 50% for the vehicle-by-vehicle analysis (meaning 50% of the vehicles screened as problematic should be confirmed as defective by the Level 1 inspections). The effectiveness criterion defined by Kentucky was met in all four states.

IRISystem as a screening device:
Does the IRISystem improve the current screening method?

The results of the evaluation were compared to SafetyNet data for the four participating states from 1997 to 1999. The percentage of vehicles placed OOS after IRISystem screening (59%) was significantly greater than the percentage of vehicles placed OOS after the current screening methods (27%), or more than twice as effective. The percentage of vehicles with brake violations also increased by a factor of 2.5, from 34% with current screening to 84% with IRISystem screening.

IRISystem as a screening device:
Other considerations

Training - One-half to one day of training was necessary. Officers who had previous experience with the IRISystem were valuable to the training sessions as they were able to share their experience directly with new trainees.

Skill level requirements - The IRISystem is an operator-friendly device and relatively easy to learn and to use. Prior experience with infrared imaging or the joystick control configuration of the camera helped some operators collect data more quickly and

more accurately than less experienced operators. Effectiveness in screening increased with practice.

Owner's manual/supportive documentation - The owner's manual was detailed and included all documentation needed to operate the IRISystem. However, the manual would benefit from the inclusion of photographs of typical problems detected with the IRISystem.

Set up locations - The IRISystem van should be set up with the center of the camera range roughly perpendicular to the direction of the traffic flow so the operator can track vehicles easily with an unobstructed view of the wheels. The IRISystem was typically set up at scale sites. The CMVs screened were traveling at speeds less than 10 mph (16 km/hr), although experienced operators were able to screen vehicles at speeds up to about 35-40 mph (56-64 km/hr).

Set up and shut down times - The IRISystem can be set up or shut down rapidly.

Mainline screening (speeds greater than 55 mph (88.5 km/hr)) - Although mainline screening was attempted with the IRISystem, no useful results were obtained. Officers indicated that mainline screening was not practical because of the difficulty in identifying the target vehicle, the inability to observe all wheels on a CMV traveling at highway speeds, the difficulty of intercepting the target CMV downstream, and overall safety concerns.

Identification of problems other than brake-related - In the field evaluation, flat tires were frequently identified with the IRISystem. Although possible with the system, no hot brakes (indicative of dragging brakes), exhaust leaks, or frame cracks were identified during the program.

Conclusions

The IRISystem can be used effectively to screen commercial vehicles for inspection of brake-related problems. This study found that:

- Sixty-eight to seventy-six percent (68% to 76%) of the wheels identified as problematic by the IRISystem, whether for brakes, flat tires, under-inflated tires, hot bearings, or other problems, were confirmed as defective by the Level 1 inspections. Most of these were brake-related defects.

- The effectiveness criterion defined by the State of Kentucky in this program for a vehicle-by-vehicle analysis was exceeded. The effectiveness criterion was that 50% of the vehicles screened as problematic by the IRISystem should be confirmed as defective by the Level 1 inspections. In this study, 59% of the vehicles screened by the IRISystem were placed out of service after Level 1 inspections. Nearly 80% of those vehicles were placed out of service for brake violations.

- The percentage of vehicles placed out of service with brake problems increased by a factor of 2.5 after using the IRISystem to screen vehicles for inspection.

For effective use, the IRISystem should be placed at inspection sites, such as scales, where commercial vehicles must apply their brakes to enter the facility. Vehicles are typically screened at speeds under 10 mph (16 km/hr), although vehicles moving at speeds up to about 35 mph (56 km/hr) can be screened by experienced operators. The IRISystem should be located such that the operator has an unobstructed view of the vehicle's wheels, and provisions can be made to identify and detain the vehicle for subsequent inspection.

Additional benefits of the IRISystem include:

- The IRISystem is a mobile device and can be used at various scale sites or other suitable inspection locations,
- The IRISystem is operator-friendly and relatively easy to learn and use,
- The infrared technology enables the IRISystem to be operated at normal roadside temperatures during both day and night, and
- The IRISystem can detect other vehicle problems such as flat tires, under-inflated tires, and hot bearings in addition to brake-related problems.

1. Introduction

1.1 Background

From 1997 to 1999, over 450,000 roadside inspections[1] of commercial motor vehicles (CMVs) were conducted in the states of Georgia, Kentucky, North Carolina and Tennessee. On average, approximately 22% of the vehicles inspected were placed out of service (OOS), and 19% had brake-related violations[2]. These inspections covered only a small percentage of the CMVs traveling on US highways. Traditionally, the selection of CMVs to be subjected to roadside inspections has been either random, based on the experience of the inspectors with the maintenance history of fleets, or based on past inspection results[3].

The InfraRed Inspection System (IRISystem) was evaluated in a field study to determine the effectiveness of this new technology for enhancing the screening of commercial motor vehicles for subsequent inspection.

The IRISystem is housed in a mobile van, as shown in Appendix A (Figure A-1), and can be positioned in a roadside inspection facility where CMVs are applying their brakes to enter the facility (Figure A-3). The IRISystem camera creates a live infrared image[4] of the CMV (Figure A-4, bottom) showing the relative temperature of wheels on the vehicle as the operator tracks the vehicle with the camera controls.

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[1] North American Standard Critical Item Inspection Procedure, 1996, CVSA; also at: http://www.cvsa.org/Inspections_Procedures/inspection_procedures.html

[2] SAFETYNET for GA, KY, NC and TN, all inspection levels, 1997 to 1999.

[3] A new system, SAFER, is under implementation, where a summary of previous inspection results assists the inspectors in the selection of vehicles to be inspected.

[4] The primary source of infrared radiation is heat. Even objects that we think of as being very cold, like an ice cube, emit infrared radiation. The warmer the object, the more infrared radiation it emits. An infrared camera reads thermal radiation, therefore detects temperature differences. Since heat is generated at the pad/drum interface during normal braking, infrared technology can be used to monitor brake systems.

A color image of the CMV is also available to the operator to identify the vehicle more easily (Figure A-4, top). Inside the van, the IRISystem operator views and interprets[5] the image on a monitor (Figure A-2). After the CMV's brakes have been applied, a functional brake appears bright white, indicating that it is "hot." A non-functional brake appears dark, or "cold" (Figures A-5 and A-6). In practice, the operator then selects the vehicle for inspection.

1.2 Scope and Objectives

The objectives of the evaluation were to determine the effectiveness of the IRISystem in enhancing the screening of CMVs in real-time at the roadside. The IRISystem was evaluated as a means to:

- Detect problematic CMV conditions--mainly brake-related defects. The IRISystem results were compared directly with roadside inspection results (on a wheel-by-wheel and vehicle-by-vehicle basis) and,
- Improve the existing screening methods. The roadside inspection results obtained after IRISystem screening were compared with roadside inspection results obtained after current screening (SafetyNet data).

Two types of analyses were performed on the IRISystem screening results: a wheel-by-wheel analysis and a vehicle-by-vehicle analysis. In the wheel-by-wheel analysis, the IRISystem results for each individual wheel were compared to Level 1 inspection results for the same wheel. In the vehicle-by-vehicle analysis, the results of the IRISystem screening (CMV problematic or not) and the Level 1 inspection (CMV

[5] The operator compares the relative temperature images of the brake systems on the vehicle's wheels. If all brakes are functioning identically (either normally or abnormally), the temperatures will be identical, and the infrared image will not show differences. Typically, a functional brake appears white or "hot", and a non-functional brake appears dark or "cold." However, a malfunctioning brake theoretically could also be whiter than a functional brake if it is dragging and causing excessive heat to be generated at the brake pad surface.

placed OOS or not) were compared. The specific location of the problematic wheels and defects were not correlated in the vehicle-by-vehicle analysis.

2. Description of the program

2.1 Participating States

Four states participated in the evaluation over the course of one year (June 1, 1999 to May 31, 2000): Kentucky, lead State for the program, Georgia, North Carolina and Tennessee.

2.2 Evaluation Plan

CMVs were screened by the IRISystem, and subsequently subjected to a full Level 1 CVSA inspection[6] by an inspector with no prior knowledge of the results of the IRISystem screening.

The IRISystem was set up at selected locations where CMVs could be readily screened and inspected, primarily while at scale sites on highways where the vehicles had to apply their brakes to enter the facility. Vehicles were typically screened at speeds under 10 mph (16 km/hr), although vehicles moving at speeds up to about 35-40 mph (56-64 km/hr) could be screened by experienced operators. A limited number of vehicles (62) with no apparent problems were also selected for Level 1 inspection to ensure that the Level 1 inspector was not biased towards finding a problem because the CMV had been selected by the IRISystem. The objectivity of the inspectors was a crucial element for the evaluation. In this report, the vehicles with no apparent problems according to the IRISystem screening are referred to as "blind, non-problematic vehicles."

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[6] The CVSA defines six levels of inspections: North American Standard Inspection (Level I), Walk-Around Driver/Vehicle Inspection (Level II), Driver-Only Inspection (Level III), Special Inspections (Level IV), Vehicle-Only Inspection (Level V), and Enhanced NAS Inspection for Radioactive Shipments (Level VI).
The Level 1 inspection includes examination of driver's license, medical examiner's certificate and waiver, if applicable, alcohol and drugs, driver's record of duty status as required, hours of service, seat belt, vehicle inspection report, brake system, coupling devices, exhaust system, frame, fuel system, turn signals, brake lamps, tail lamps, head lamps, lamps on projecting loads, safe loading, steering mechanism, suspension, tires, van and open-top trailer bodies, wheels and rims, windshield wipers, emergency exits on buses and hazardous materials requirements, as applicable.

Vehicles, for which the IRISystem detected a potential problem, are referred to as "problematic vehicles." In contrast, vehicles for which violations to safety regulations were found during the Level 1 inspection are referred to as "defective vehicles."

The effectiveness criterion defined by Kentucky was fifty percent (meaning 50% of the vehicles screened as problematic should be confirmed as defective by the Level 1 inspections). With the current screening methods, 19% of the vehicles inspected in Kentucky were placed OOS and 28% had brake violations[7]. Details of the evaluation plan can be found in Appendix B.

2.3 Data Collection Protocol

At least two inspectors were needed for data collection: one for the IRISystem and one for Level 1 inspections. Vehicles were selected for a Level 1 inspection by the IRISystem operator. Upon completion of the screening, the IRISystem operator filled out the IRISystem screening report (Appendix C), and printed the IRISystem photographs of the selected vehicle together with an indication of the suspected problem area (Appendix A, Figures A-5 and A-6). A wheel was judged as being either problematic or normal. A problematic wheel or brake appeared, according to the IRISystem operator, significantly colder or hotter than the other wheels or brakes on the vehicle. A normal wheel (or brake) did not, according to the IRISystem operator, appear hotter or colder than the other wheels (or brakes) on the vehicle. The Level 1 inspection was performed by one or more other inspectors with no prior knowledge of the IRISystem screening results. The Level 1 inspector identified vehicle or driver defects in the CVSA report, as required by Level 1 inspections (Appendix D). The IRISystem screening report, the IRISystem photograph(s), and the Level 1 inspection report were stapled together for further analysis. The data collection protocol used throughout the evaluation is included in Appendix E. Subsequently, the results were reviewed and entered in a spreadsheet by the evaluation team for further analysis.

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[7] SAFETYNET data, all inspection levels, 1997 to 1999.

False positives were defined as follows (see Table 1). For the wheel-by-wheel analysis, no defect (or FMCSR violation) was found on a wheel previously judged problematic by the IRISystem operator. For the vehicle-by-vehicle analysis, a vehicle judged as problematic by the IRISystem operator was not placed OOS during the Level 1 inspection.

False negatives were defined as follows. For the wheel-by-wheel analysis, at least one defect (or FMCSR violation) was found on a wheel previously judged normal by the IRISystem operator. For the vehicle-by-vehicle analysis, a vehicle judged as blind, non-problematic by the IRISystem operator was placed OOS during the Level 1 inspection.

Table 1. False positive and false negative cases in the wheel-by-wheel and vehicle-by-vehicle analyses.

	Wheel-by-wheel analysis	**Vehicle-by-vehicle analysis**
False positive	IRISystem: Problematic wheel or brake Level 1: No defect found on the *same* wheel	IRISystem: Problematic vehicle (any wheel) Level 1: Vehicle not placed OOS
False negative	IRISystem: Normal wheel or brake Level 1: At least one defect found on the *same* wheel	IRISystem: Blind, non-problematic vehicle Level 1: Vehicle placed OOS

3. Results

3.1 Summary of Data Collected

Table 2. Summary of data collected

	All states
Number of CMVs inspected	392
Percentage of blind, non-problematic CMVs	*16%*
Percentage of 3-S2†† CMVs	*88%*
Percentage of loaded 3-S2 CMVs	*70%*
Number of days in use (for evaluation purposes)	77
Percentage of problematic (cold) wheels†	*11%*
Percentage of problematic (hot) wheels†	*1%*
Average No. of IRISystem-identified problems per 3-S2	1.3

† As identified by the IRISystem operator †† 3-axle tractor, 2-axle trailer combination

As shown in Table 2, nearly 400 CMVs were inspected following IRISystem screening by the four states in one year. On average, 16% of the inspected vehicles were blind, non-problematic vehicles to serve as a control group. Eighty-eight percent of the CMVs included in this study were 3-S2 tractor-trailer combinations. Other types of CMVs inspected included bobtail tractors, straight 2 or 3-axle trucks, other tractor-trailer combinations (e.g. mobile home trailers). Approximately 70% of the CMVs inspected were loaded vehicles.

For the evaluation, the IRISystem was in use for a total of 77 days. The total number of CMVs inspected per day was not limited by the IRISystem but rather by the number of inspectors available and by the requirement for Level 1 inspections[8].

Approximately 10% of the wheels screened by the IRISystem were identified as problematic and cold, and about 1% of the wheels screened by the IRISystem were identified as problematic and hot. The average number of problematic wheels identified per CMV by the IRISystem operator was 1.3, indicating that the operator typically identified and reported 1 to 2 problematic wheels. Some wheels may not have been visible to the operator. In this evaluation, when a wheel was not visible to the operator, it was assumed to be problem-free or "normal." The number of wheels that could not be assessed visually with the IRISystem is unknown.

Set-up locations were chosen by the individual states. In general, the IRISystem van was set up at scale sites on highways (Appendix A, Figure A-3). Other locations included state roads near a port of entry in Georgia. Appendix F shows typical set-ups for the IRISystem. The maximum speed of CMVs screened was 35-40 mph (56-64 km/hr), and the average screening speed was about 10 mph (16 km/hr). Although mainline screening (speeds greater than 55 mph (88.5 km/hr)) was attempted with the IRISystem, no useful results were obtained. Officers indicated that mainline screening was not practical because of the difficulty in identifying the target vehicle, the inability to observe all wheels on a CMV traveling at highway speeds[9], the difficulty of intercepting the target CMV downstream, and overall safety concerns.

To view the heat output of the brakes on the near-side wheels of the vehicle properly, the IRISystem camera was positioned nearly perpendicular to the traffic flow (Appendix A, Figure A-5). Near-side wheels were more difficult to assess than far-side wheels. Wheel covers on the near-side wheels tended to obscure the infrared image of

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[8] The IRISystem screening was completed typically in several minutes while the Level 1 inspection required up to one hour (when multiple violations of safety regulations were found). To keep the evaluation objective, the IRISystem operator did not conduct the Level 1 inspections. In future screening use, CVSA inspections of a level other than Level 1 could be conducted at the inspector's discretion to optimize the inspectors' time.

[9] At highway speeds, the time that the near-side wheels are visible to the operator is too brief for the operator to detect a problem.

the wheels, and the near-side wheels passed through the camera range more quickly than the far-side wheels (Appendix A, Figure A-6). On average, the majority of problems identified during the IRISystem screening were located on the trailer wheels on the far side of the CMV with respect to the IRISystem van (Figure 1). However, this result was dependent on the operator, as shown in Appendix G where figures similar to Figure 1 are included for each state.

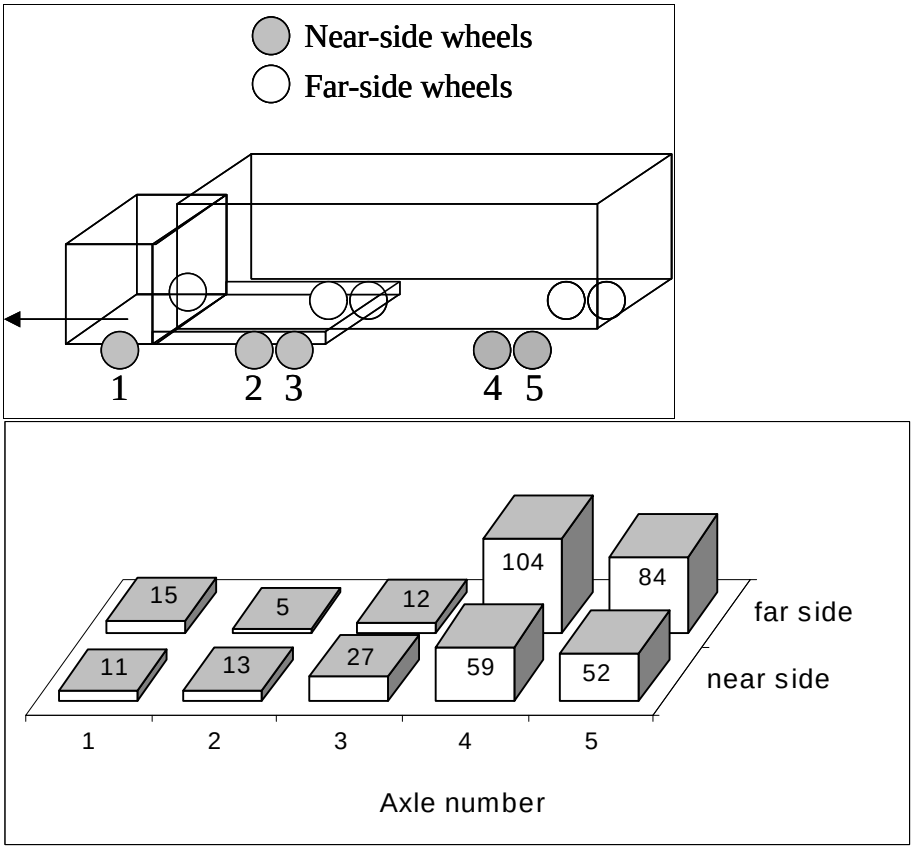

Figure 1. Number of problematic wheels identified by IRISystem as a function of wheel location on a 3-S2 CMV. The data are for all states. The arrow indicates the direction of the vehicle. The schematic illustrates the near-side and far-side wheel location as well as the axle numbers.

The presence of brake defects or deficiencies was a good indicator that other repairs on the CMV were needed, and led to additional violations. Figure 2 illustrates the average number of FMCSR violations reported for the CMVs screened with the IRISystem. Violations were grouped into one of two categories: non-wheel-specific violations and wheel-specific violations. Each of these categories of violations was

further sub-divided into brake-related and other violations. Typical examples for each of these types of violations are listed in Table 3. As shown on Figure 2, additional violations were discovered for most vehicles, whether blind or problematic. Plots similar to Figure 2 are included in Appendix H for each state.

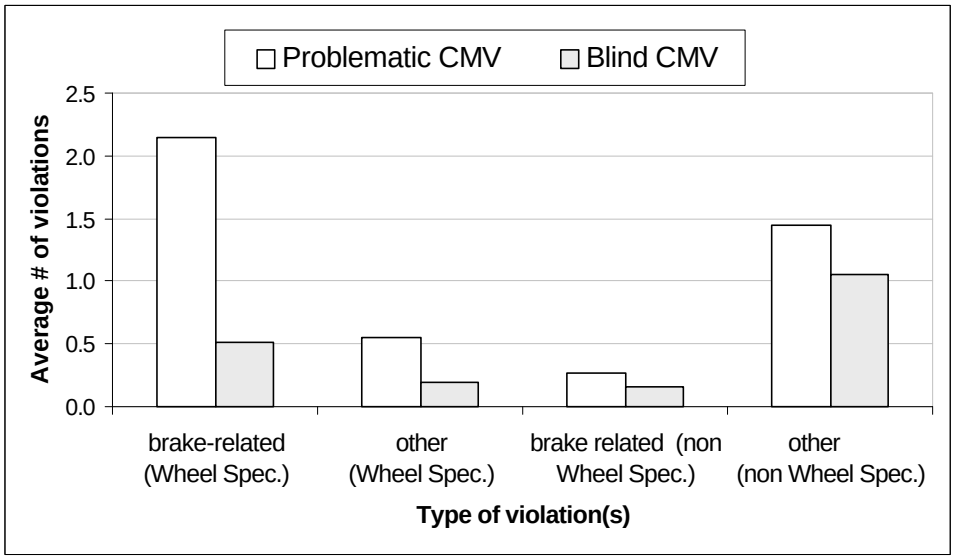

Figure 2. Average number of FMCSR violations reported in Level 1 inspections for CMVs screened with the IRISystem.

Table 3. Examples of FMCSR violations

Types of violations	Brake-related	Other (non brake-related)
Wheel-specific	• Readjustment limit exceeded [396.3(a)1]* • Cracked, loose or missing lining [393.47]*	• Tire violation, e.g. side wall is cut, worn or damaged to the extent that the ply cord is exposed [393.75(a)]*
Non-wheel-specific	• Any brake hose violation, e.g. hose with audible air leak.	• Any driver violation

* Section in Title 49 of the Code of Federal Regulations

3.2 Wheel-by-wheel analysis: Identification of problematic wheels. Comparison of the IRISystem screening results with the CVSA inspections results.

The IRISystem operator identified each wheel of the screened CMV as normal or problematic. If problematic, the operator specified "cold" or "hot" (Appendix E). Table 4 lists the percentage of agreement between the IRISystem screening results and the Level 1 inspection results for all wheels screened by the IRISystem. Figure 3 illustrates these results graphically. Similar results are included in Appendix I for each state. As listed in Table 5, two types of comparisons were conducted for the IRISystem-identified cold wheels. First, the percentage of agreement between IRISystem results and Level 1 Inspection results were assessed by seeking correlation between cold wheels and wheel-specific FMCSR violations, whether brake-related or not (Table 3). Second, the correlation between IRISystem cold wheels and brake-related FMCSR violations, whether wheel-specific or not (Table 3), was investigated.

Table 4. Percentage agreement between the IRISystem screening results and the Level 1 inspection results. State-specific results are included in Appendix I.

IRISystem diagnostic		**All states**
Normal wheels	# of wheels (% total)	3326 (88%)
	% agreement †	***85%***
	% disagreement †	*15% **
Cold Wheels	# of wheels (% total)	399 (11%)
	% agreement †,1 *(% disagreement* †,1*)*	***68%*** *(32% *)*
	% agreement †,2 *(% disagreement* †,2*)*	**76%** *(24% *)*
Hot Wheels	# of wheels (% total)	44 (1%)
	% agreement † *(% disagreement* †*)*	***68%*** *(32% *)*
Total # wheels		3769

† Between IRISystem screening results and Level 1 inspection results
1 Level 1 inspection identified one or more wheel-specific defect, whether brake-related or not (Table 5).
2 Level 1 inspection identified one or more brake-related defect, whether wheel specific or not (Table 5).
* False positives ** False negatives

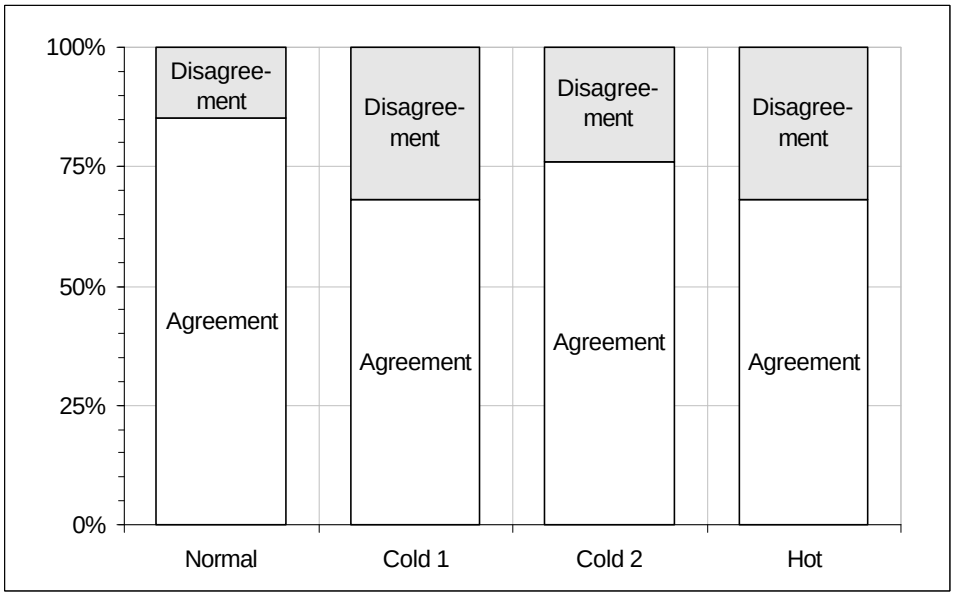

Figure 3. Percentage of agreement between IRISystem screening results and Level 1 inspection results.

Table 5. Correlation between IRISystem and Level 1 inspection results

Types of correlation	IRISystem diagnostic	FMCSR violations	Legend in Figure 3
1	Cold wheels	Wheel-specific violations (brake-related or not)	Cold 1
2	Cold wheels	Brake-related violations (wheel-specific or not)	Cold 2

Wheels identified as normal by the IRISystem operator

Eighty-five percent of the wheels identified as normal by the IRISystem operator were violation-free in the Level 1 inspection (the inspector did not find any FMCSR violation at the same wheel location).

The disagreement between the IRISystem and the Level 1 inspection results was due in part to (1) the assumption that a wheel not visible to the IRISystem operator was normal, and (2) the preventative nature of some Level 1 inspection violations. For

example, chafing or rubbing brake hoses could indicate a future problem that may not affect the vehicle's braking capability at the time of the inspection.

Wheels identified as problematic by the IRISystem operator

Approximately 12% of the total number of wheels screened were identified as problematic by the IRISystem operators in the field evaluation. Most of these (90%) were cold problematic wheels. A cold problematic wheel was typically a wheel with no braking action, whereas hot problematic wheels may be caused by hot bearings, flat tires or dragging brakes.

Cold wheels

Sixty-eight percent of the cold problematic wheels also had one or more wheel-specific violations, whether brake-related or not. This percentage increased to 76% for brake-related violations, whether wheel-specific or not.

The mismatch between the IRISystem and the Level 1 inspection results was not surprising because these techniques are based on different principles. The IRISystem provided a relative rather than an absolute assessment of brake system performance on a vehicle through a visual indication of the heat generated by braking forces. For example, the following disagreement was observed frequently during the evaluation. A brake, which appeared cold in the IRISystem screening, passed the inspection when its adjustment was nearly at the limit. This brake may have had less braking action than the other brakes and appeared colder.

Disagreement between the IRISystem screening and the Level 1 inspection results may also occur for exempt vehicles. For example, the IRISystem screening accurately detected cold wheels on mobile home trailers because the trailers were not equipped with brakes. Another discrepancy can occur if a tractor drops a trailer, which it has been pulling all night, and picks up another trailer that has been parked overnight. The tractor brakes may then appear hotter than the trailer brakes.

Hot wheels

The Level 1 inspection showed that 68% of the IRISystem-identified hot problematic wheels had a wheel-specific violation. Only one-third of the hot problematic wheels, for which the IRISystem and the inspection results matched, were brake related. The most common cause for an IRISystem-identified hot problematic wheel was a flat tire, which can be identified readily by an inspector without the use of the IRISystem technology. Theoretically, the IRISystem identify dragging brakes, which cause excessive heat. However, no dragging brakes were identified in this field evaluation.

In all four states, the effectiveness criterion defined by Kentucky (see page 4) was met. This result was consistent with earlier studies using a drive-over array of infrared sensors where infrared technology was shown to be effective in identifying inoperative and significantly misadjusted brakes[10].

Effect of vehicle loading

It was anticipated that the IRISystem would be more effective as the vehicle loading increased. However, the effect of loading could not be determined conclusively from the study data. The gross vehicle weights of the CMVs were not collected, only whether the CMVs were loaded or empty. The percentage agreement between the IRISystem screening and Level 1 inspection results was:

- for normal wheels: 86% loaded versus 88% empty.
- for cold wheels: 68% loaded versus 67% empty.

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[10] S. J. Shaffer and P. A. Gaydos, 1998, "Development, Evaluation and Application of Performance-Based Brake Testing Technologies," Final report, FHWA-MC-98-048, pp. 8-35 to 8-43. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/8mn01!.pdf

3.3 Vehicle-by-vehicle analysis: Identification of Out-Of-Service CMVs. Comparison of the IRISystem screening results with the FMCSR inspections results.

In normal use of the IRISystem for screening brakes, i.e. not in the context of an evaluation, only problematic vehicles would be subjected to inspections. Therefore, this section presents results separately for problematic vehicles and blind, non-problematic vehicles.

For all of the participating states, 59% of vehicles on average screened by IRISystem as problematic were placed OOS in the subsequent Level 1 inspection (Table 6 and Figure 4b). Seventy-nine percent of the screened vehicles, which were placed OOS, were placed OOS as a result of brake violations, among which 22% had brake and other OOS violations (for example, driver related violations). Twenty-one percent of the problematic vehicles were placed OOS because of other-than-brake violations only.

As shown in Table 6 and Figure 4(a), the percentage of blind, non-problematic vehicles placed OOS was 19% (false negatives), considerably less than for the problematic vehicles. Two-thirds (2/3) of the blind, non-problematic CMVs were placed OOS as a result of brake violations and one-third (1/3) as a result of other-than-brake violations.

Table 6. Percentage of CMVs placed OOS after IRISystem screening

	Not placed OOS	**Placed OOS**			
		Any criteria	*Brake violation(s) only* ††	*Brake and other violation(s)* ††	*Other-than-brake violation(s)* ††
All CMVs (392)	47% (186)	53% (206)	*57% (118 / 206)*	*21% (43 / 206)*	*22% (45 / 206)*
Blind, non-problematic CMVs (62)	81% (50)	**19%** * (12)	*58% (7 / 12)*	*8% (1 / 12)*	*33% (4 / 12)*
Problematic CMVs (330)	41% ** (136)	**59%** (194)	***57%*** *(111 / 194)*	***22%*** *(42 / 194)*	***21%*** *(41 / 194)*

† Problematic vehicles only. †† Percentage of OOS vehicles only.
* false negatives ** false positives

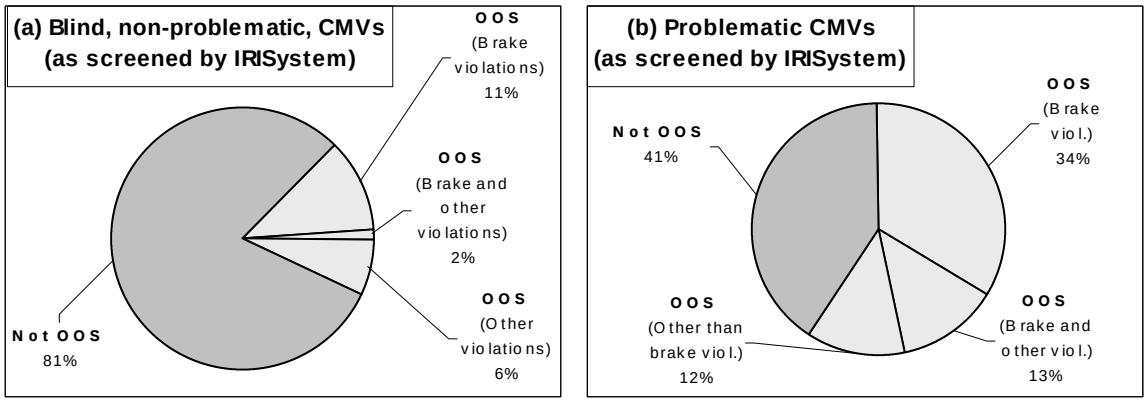

Figure 4. Percentage of CMVs placed OOS in all four states after IRISystem screening (a) blind, non-problematic vehicles and (b) problematic vehicles. These plots only include CMVs placed OOS in the Level 1 inspection. Some CMVs screened by IRISystem were not subsequently placed OOS.

Results for the individual states can be found in Appendix J.

On average for all four of the states, IRISystem identified the OOS violations on 74% of the CMVs placed OOS. This means that, for 74% of the CMVs placed OOS, the IRISystem-identified defects led to OOS in the subsequent Level 1 inspection. The vehicles missed by IRISystem were placed OOS due to other causes (for example, driver violations).

3.4 IRISystem as A Brake Screening Device

3.4.1 Does the IRISystem improve the current screening method?

SAFETYNET is a state level information management system for motor carrier safety, which operates in every state. It captures interstate and intrastate driver/vehicle inspection data, accident data, carrier compliance reviews, enforcement data, and carrier identification data.

The results of the evaluation were compared to SafetyNet data for the four participating states from 1997 to 1999, as shown in Figure 5.

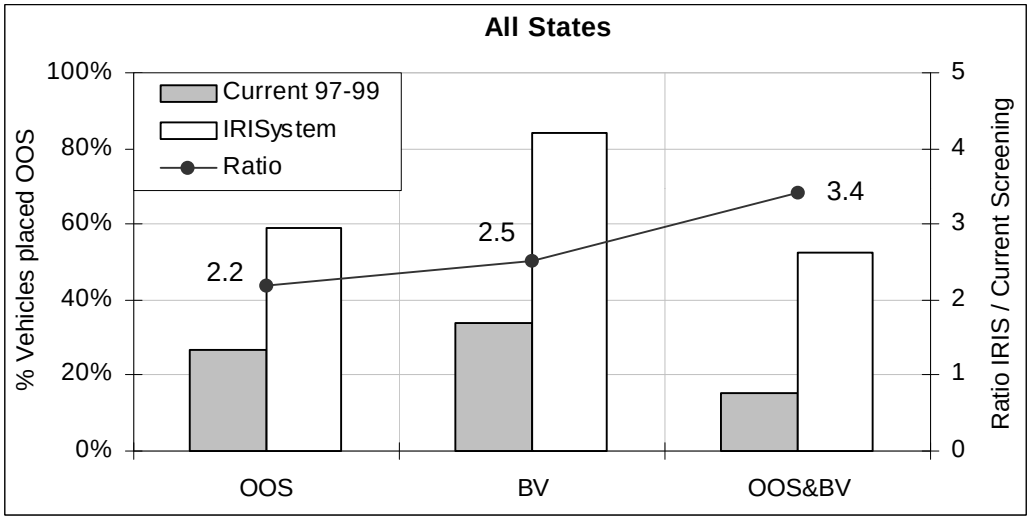

Figure 5. Comparison of IRISystem Results (no blind vehicles) with SAFETYNET data (current screening methods) for out-of-service (OOS) vehicles and brake violations (BV).

Figure 5 shows, the percentage of vehicles for all four states subjected to a Level 1 inspection that:

- were placed OOS ("OOS"),
- had brake violations ("BV"), and
- were placed OOS and had brake violations ("OOS & BV").

The brake violations reported are not necessarily OOS violations. For the IRISystem screening, the data are for the total number of vehicles for which the

IRISystem identified problematic wheels. The results for current screening methods (1997 through 1999 SAFETYNET data) and after IRISystem screening are compared. The ratio of the percentage of CMVs placed OOS after IRISystem screening divided by the percentage of CMVs placed OOS after current screening is also plotted on Figure 5. Results for each state are included in Appendix K.

As seen in Figure 5, the percentage of vehicles placed OOS after IRISystem screening (59%) was significantly greater than the percentage of vehicles placed OOS using current screening methods (27%), or more than twice as effective. The percentage of vehicles with brake violations also increased by a factor of 2.5, from 34% with current screening to 84% with IRISystem screening. Finally, the percentage of CMVs placed OOS with BV was much greater after using IRISystem screening (by a factor of 3.4).

3.4.2 Logistics considerations

Training requirements

One-half day to one day of training was necessary. During the field evaluation, an experienced operator presented to an audience who had already received and presumably reviewed the owner's manual, the basic principles of infrared imaging, the components of the IRISystem and its basic principles of operation. In particular, the set up, operation, shut down, and maintenance operations were explained. Following the formal training, trainees practiced operating the IRISystem. Level 1 inspections were not conducted during the IRISystem training.

- Officers who had previous experience with the IRISystem were valuable to the training sessions, as they were able to share their experience directly with the new trainees.
- More emphasis during training should be placed on the possibility of hot problematic brakes (e.g. dragging overheating brakes or dry wheel bearings). Only a small percentage of hot wheels were detected in this evaluation, perhaps as a result of lack of training of the inspectors, rather than a low occurrence of the defect.

Skill level requirements

Differences were observed in the performance of the system as a function of operator. Prior experience with infrared imaging or with the joystick control configuration of the camera helped some operators collect data more quickly and more accurately.

Owner's manual/supportive documentation

The owner's manual includes all documentation needed to operate the IRISystem. However, photographs of typical problems detected with the IRISystem should be added to the manual to help new operators identify problematic wheels. Also, information should be included to guide operators when visibility is limited (for example, by certain wheel designs or dust covers).

Set up locations

The IRISystem van should be set up such that the center of the camera range is perpendicular to the direction of the traffic flow. The IRISystem was typically set up at scale sites on US highways. The CMVs screened were traveling at maximum speeds of 35-40 mph (56-64 km/hr), though usually less than 10 mph (16 km/hr). The scale sites were chosen for several reasons:

- The CMVs were applying their brakes in order to enter the facility,
- The CMVs were traveling at low speed making observation easier,
- Inspections could be conducted near the IRISystem van, facilitating the interception of the CMVs with identified problems, and
- The IRISystem van could be set up in a safe environment for the inspectors and the CMV operators.

Set up and shut down times

The IRISystem can be set up or shut down rapidly.

Maintenance costs and effort requirements

Maintenance costs and effort requirements were not available for this study.

3.4.3 Performance considerations

Mainline screening

Mainline screening tests (speeds greater than 55 mph (88.5 km/hr)) were attempted as part of the evaluation. However, all of the IRISystem operators indicated that it was too difficult to identify the target vehicle and to observe all wheels on a CMV traveling at highway speeds. Also, intercepting the vehicle downstream would require significant efforts of coordination and present safety concerns for the IRISystem operator, the Level 1 inspector, and the CMV operator. The IRISystem van should be set up far enough away from moving traffic to ensure the safety of the operators and to permit sufficient time for observation of the vehicle being screened. The distance required between the CMV and the IRISystem van increases with the speed of the vehicle being screened.

Identification of problems other than brake-related

The IRISystem is capable of identifying problems other than brake-related defects, such as under-inflated tires, wheel bearings, cracks in the frame, or exhaust leaks. In the field evaluation, flat tires were frequently identified with the IRISystem. This can be valuable for inspection of inner tires, which may not always be seen using current screening methods. Some cases of tires with high tread wear were seen as well as a couple of hot wheel bearings. No hot brakes (indicative of a dragging brake) were identified. The majority of the problematic wheels reported by the IRISystem operator were cold brakes (90%).

4. Conclusions

The IRISystem can be used effectively to screen commercial vehicles for inspection of brake-related problems. This study found that:

- Sixty-eight to seventy-six percent (68% to 76%) of the wheels identified as problematic by the IRISystem, whether for brakes, flat tires, under-inflated tires, hot bearings, or other problems, were confirmed as defective by the Level 1 inspections. Most of these were brake-related defects.
- The effectiveness criterion defined by the State of Kentucky in this program for a vehicle-by-vehicle analysis was exceeded. The effectiveness criterion was that 50% of the vehicles screened as problematic by the IRISystem should be confirmed as defective by the Level 1 inspections. In this study, 59% of the vehicles screened by the IRISystem were placed out of service after Level 1 inspections. Nearly 80% of those vehicles were placed out of service for brake violations.
- The percentage of vehicles placed out of service with brake problems increased by a factor of 2.5 after using the IRISystem to screen vehicles for inspection.

For effective use, the IRISystem should be placed at inspection sites, such as scales, where commercial vehicles must apply their brakes to enter the facility. Vehicles are typically screened at speeds under 10 mph (16 km/hr), although vehicles moving at speeds up to about 35-40 mph (56-64 km/hr) can be screened by experienced operators. The IRISystem should be located such that the operator has an unobstructed view of the vehicle's wheels, and provisions can be made to identify and detain the vehicle for subsequent inspection.

Additional benefits of the IRISystem include:

- The IRISystem is a mobile device and can be used at various scale sites or other suitable inspection locations,
- The IRISystem is operator-friendly and relatively easy to learn and use,
- The infrared technology enables the IRISystem to be operated at normal roadside temperatures during both day and night, and
- The IRISystem can detect other vehicle problems such as flat tires, under-inflated tires, and hot bearings in addition to brake-related problems.

Appendix A

IRISystem Photographs

Figure A-1. The IRISystem, showing the housing minivan, and the camera mount on the roof (Photo courtesy of J. Bibb).

Figure A-2. The IRISystem minivan interior with video screens, VCRs and the joystick which operates the camera.

Figure A-3. The IRISystem, set-up at a scale site in Kentucky.

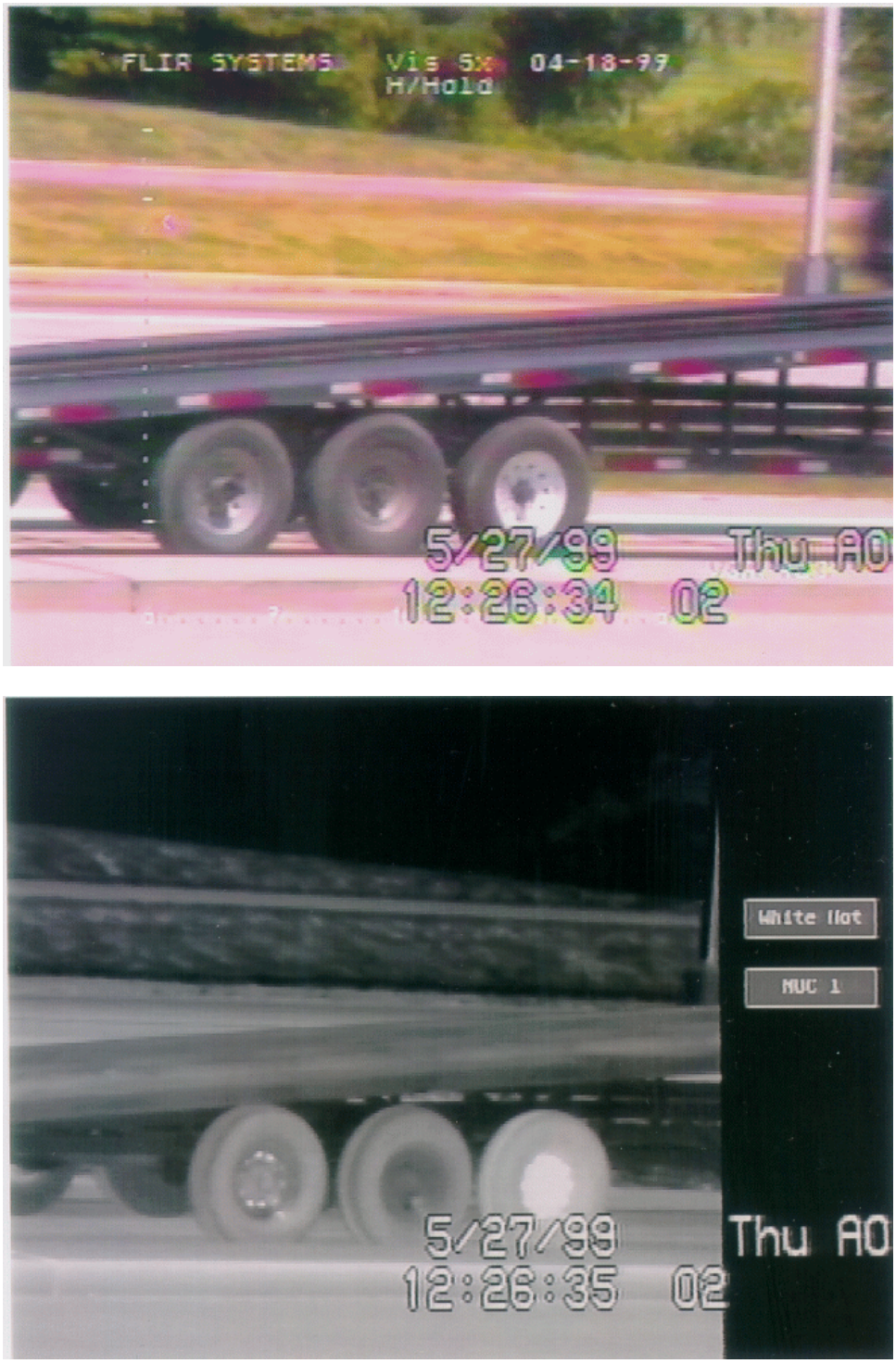

Figure A-4. Color and corresponding thermal images of a screened CMV.

Figure A-5 **IRISystem infrared photograph showing the right side of axles 4 and 5 for a tractor-trailer traveling to the right of the photograph. In comparison with wheel 4R, wheel 5R (circled) does not show white though the holes and indicates a potential defective braking system at that wheel.**

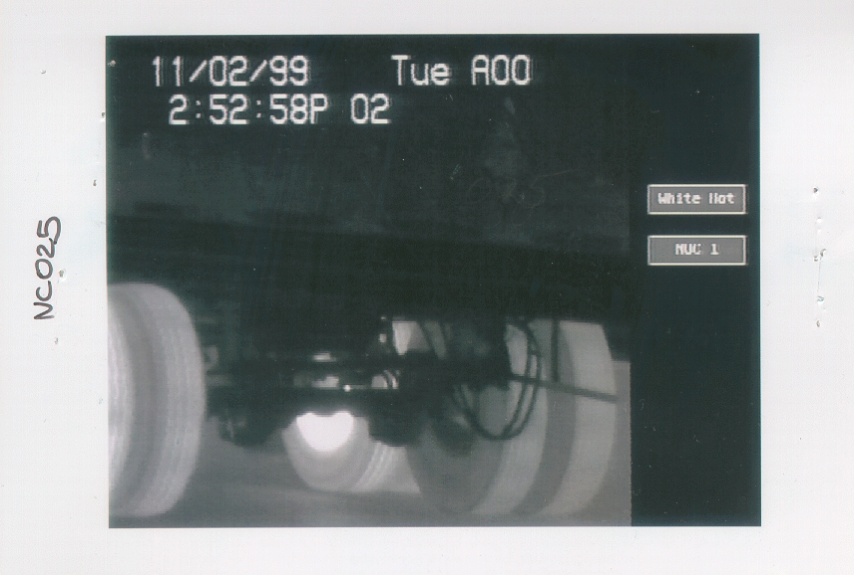

Figure A-6 **IRISystem infrared photograph showing the left side of axles 4 and 5 for a tractor-trailer traveling to the right of the photograph. In comparison with wheel 5L, the drum for wheel 4L does not show white and indicates a potential defective braking system at that wheel.**

Appendix B

IRISystem Evaluation Plan

Evaluation Plan for IRISystem Infrared Brake Screening Project

DTFH61-96-C-00044, Task Order Battelle 7704, Subtask 19
December 1999

Objective: To evaluate the effectiveness of the IRISystem (infrared imaging and video) for use as a screening tool on commercial vehicles for detecting bad brakes and unsafe vehicles due to braking.

Definitions: There are three definitions given in each group below, each based on a specific method of rating brake performance.

Definitions of a problematic brake:

1) A brake that cannot meet a minimum force or torque level[1].
2) A brake that is found to have a Federal Motor Carrier Safety Regulations (FMCSR) defect when inspected by a CVSA-certified inspector or a qualified mechanic.
3) For the IRISystem, a problematic brake is one which, in the judgement of the inspector or operator, is significantly colder or hotter than the other brakes on the vehicle.

Definitions of an unsafe vehicle:

1) A vehicle with insufficient stopping capability in its current loading condition[2].
2) A vehicle which is placed out-of-service (OOS) by a CSVA-certified inspector as a result of a Level 1 inspection. For this study, the OOS must be due to brake-related defects found during the inspection.
3) The IRISystem does not currently have an unsafe vehicle definition. A proposed definition would parallel the CVSA definition: a vehicle is unsafe if 20 percent or more problematic brakes are identified.

Effectiveness of the IRISystem for use as a screening tool[3]: As shown in Figure B1, all brakes for which both an IRISystem screening and a CVSA inspection report are available will be divided into two primary groups, based on whether or not the IRISystem screening identified a potential brake problem. Each group will in turn be sub-divided according to whether or not the defective brake was identified during a CVSA Level 1 inspection. The results will fall into one of four categories from which the evaluation of

---

[1] A brake is considered weak if it cannot produce a minimum brake force to wheel load ratio (BF/WL) of 0.25 for a steer-axle brake or 0.35 for a non-steer axle brake.

[2] For example, the vehicle cannot perform a stop within 12 meters (40 feet) from 32 km/hr (20 mph), or cannot produce a deceleration of 4.3 m/s^2 (14 ft/sec^2) during the stop. Alternatively, the vehicle cannot produce an equivalent deceleration, ratio of total brake force to gross vehicle weight (BF_{tot}/GVW) of 0.4. The equivalent deceleration can be measured using a performance-based brake tester (PBBT).

[3] Note: for their own study, Kentucky will consider the system effective if 50 percent or more of the brakes that are inspected with the IRISystem and are deemed to be problematic (hot or cold) are also found to have a brake-related FMCSR violation.

the effectiveness of the IRISystem can be quantified.

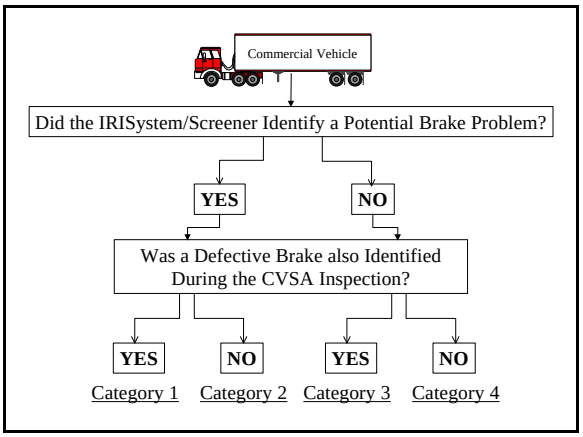

Figure B1. Possible outcomes of IRISystem screening and CVSA Level 1 inspection. The categories apply both to individual brakes and to vehicles considered out-of-service.

Categories 1 and 4 indicate the level of effectiveness of the IRISystem as an accurate screening tool, while categories 2 and 3 indicate its limitations (inaccuracy). The results will be presented in one or more pie-charts, representing, 1) the brakes for which the IRISystem operator identified a potential brake problem, or 2) the brakes for which the IRISystem operator did not observe any potential brake problems. An example from a hypothetical population of brakes is shown in Figure B2.

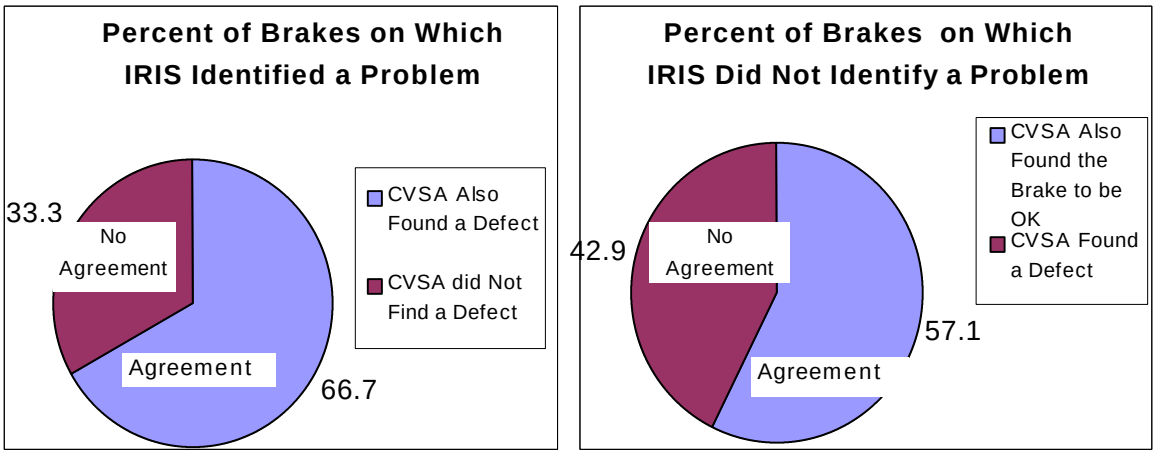

Figure B2. Example results of the effectiveness of the IRISystem used as a screening tool from a hypothetical population of brakes.

Vehicle Population Requirements: An objective evaluation requires that an equal number of "good" and "bad" vehicles, as defined by the IRISystem, be selected for a

subsequent CVSA Level 1 inspection. Since the participating States are primarily interested in using the IRISystem for identifying inoperative brakes (for which it has already been shown that an infrared system can be effective[4]), we think that the 50/50 screening can be limited to a few days of operation, such that a minimum of 100 vehicles are evaluated from each State.

The above data analysis will be made for 100 vehicles on which valid results of both brake evaluation methods are available. If resources are available, more detailed studies, such as the influence of vehicle speed, terrain, vehicle loading, climatic conditions, State practices, and IRISystem operator subjectivity, will be included.

Comparison to Brake Performance: In keeping with FHWA's goal of improved highway safety through increased use of performance-based methods, it is important that the results of an IRISystem screening also be compared with the actual braking capability of the vehicle. Since a CVSA Level 1 inspection only addresses visual "defects", and not brake performance, the correlation between IRIS-selected problematic vehicles and stopping capability cannot be completely assessed through the above evaluation. Such a correlation can only be accomplished either by performing an actual vehicle stopping test, or using a performance-based brake tester (PBBT). The IRISystem screening is based on relative temperatures of components on a given vehicle. As an example, if the brake linings on a vehicle have been replaced with linings that have a lower coefficient of friction than the original linings, or if the fit between the linings and drums is poor, then the stopping capability of the vehicle will be diminished. However, the brake drum temperatures would be similar. Therefore the diminished, and possibly insufficient stopping capability of the vehicle would not be detected by the IRISystem. These types of vehicles, which have inadequate braking capability, are of primary interest to improving highway safety. As such, it would be valuable for the evaluation to include a few comparisons between the IRISystem results and a PBBT check of the same vehicle, or a stopping distance test. If additional resources become available, relationships such as those detailed above will also be sought between the IRISystem "inspection" and the results of one of these performance-based methods.

Additional Considerations for the Evaluation: During earlier field tests of PBBTs, additional factors were included in the evaluation in order to assist with a cost/benefit analysis. Some of these factors may be applicable to the overall evaluation of the IRISystem, and are listed below. These will be included in the analysis to the extent possible.

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[4] Earlier studies of a drive-over array of infrared sensors showed the technique effective for identifying inoperative and significantly misadjusted brakes. These results are contained in Section 8.4.4 of the Final Report submitted to FHWA in January, 1998, entitled "Development, Evaluation, and Application of Performance-Based Brake Testing Technologies."

Factors Concerning Technical Operation

Can screening be done at highway speed?
What are the best locations for use as a brake screening tool?
How effectively can other types of defects be detected using the IRIS? Examples include tires, wheel bearings, cracks in frames and suspension, or exhaust leaks.
How would the number of vehicles selected through screening with IRISystem change if a greater number of CVSA-certified inspectors were available for performing a Level 1 inspection?

Factors Concerning Cost of Ownership and Operation

What are the training requirements?
What is the set-up time?
What are the maintenance costs and effort requirements?
How adequate are the owners/users manuals?
What are the skill level requirements of the IRISystem operator?

Data required for Evaluation: The relevant data from both the IRISystem screening and the CVSA Level 1 inspection will be entered into a spreadsheet by the States participating in the evaluation. An example is shown in Table B1. These spreadsheet data files will be forwarded to Battelle, along with hard copies of the IRISystem photo(s) and CVSA inspection report for each vehicle.

For a vehicle "selected" using the IRISystem for screening, each brake on the vehicle will be sorted into one of four categories, and entered into the spreadsheet. The possible outcomes for each brake as a result of the IRISystem screening will be:

a) OK
b) cold (as defined above)
c) hot (as defined above)
d) not visible

The CVSA Level 1 inspection results will be used by the participating states to enter the data into the spreadsheet using the following categories:

a) The wheel was OK
b) A brake had an FMCSR defect
c) There was some other (wheel-specific) FMCSR defect (such as rim or tire)
d) There were non-wheel-specific FMCSR violations found (such as driver, frame, or cargo).

Table B1. Example of data entry into spreadsheet required for evaluation.

Date:	Location:	Terrain	CVSA #
Vehicle Speed	Vehicle Weight		IRISystem time

		IRISystem				**CVSA**			
Wheel #	Posi-tion	IRISystem Shows **Hot**	IRISystem Shows Cold	IRISystem Shows **OK**	Not Visible	Brake Defect	Other Defect (wheel-specific)	**OK**	Non-wheel-specific defects
1	1L			1				1	
2	1R			1				1	
3	2L		1					1	
4	2R	1					1		
5	3L			1		1			
6	3R				1	1			
7	4L			1				1	
8	4R		1			1			
9	5L			1				1	
10	5R				1	1			
Non-Wheel-Specific Defects									3

Appendix C

IRISystem Screening Report

IRISystem Screening Report

IRISystem Report # _____ Operator: _____

CVSA Inspection # _____ Date / Time: _____

Location: _____

Weather: _____ Terrain: _____

Terrain Types:	Grade > 6%
	Grade 2% to 5%
	Grade < 2%
	Metro Area

IRISystem Detectable Faults

1L ☐ ---- 1 ---- ☐ 1R _____

2L ☐☐ ---- 2 ---- ☐☐ 2R _____

3L ☐☐ ---- 3 ---- ☐☐ 3R _____

4L ☐☐ ---- 4 ---- ☐☐ 4R _____

5L ☐☐ ---- 5 ---- ☐☐ 5R _____

Fault Types:

1. Cold Brake
2. Hot Brake
3. Hot Tire
4. Hot Bearings
5. Other

Comments / Remarks (IRISystem Only)

☐ **IRISystem Checked OK**

Name/Date:

Comments / Remarks (Other than IRIS)

Name/Date:

Drawing of the location set-up (Back of IRISystem report)

Show the following on the drawing:

- Roadway
- Arrow for direction of travel of screened vehicles
- Approx. speed of vehicles
- Estimated distance from IRISystem to screened vehicles
- Location for Level 1 Inspection
- Estimated distance from IRISystem to Level 1 Inspection

Appendix D

Level 1 Inspection Report

COMMERCIAL VEHICLE ENFORCEMENT
COFFEE COUNTY WEIGH STATION
1150 FOSTER AVENUE
NASHVILLE, TN. 37249-1000
931-723-5062

DRIVER VEHICLE INSPECTION REPORT
Report #:
Date
Time Started: 07:45 Time Ended: 08:30
Insp. Level: 1 (Full Inspection)

Fleet Name
Fleet Address
ICC #: DOT #
Phone #: Fax #:

Driver
License #:
DOB
State #:
Cargo: EMP
State: GA

Location: I-24 WEST
Highway: I-24 W
Shipper: NA

MilePost: 116
County: COFFEE

Origin:
Destination:
Shipping Paper #: NA

VEHICLE IDENTIFICATION

Unit	Type	Make	Yr	Company	License	State	CVSA #	HAZARDOUS MATERIALS HM Code/Class	Qty	Wgt
1	TT	INTL	92	003	G18385	GA				
2	ST	FRUE	99	3952	2480GN	GA				

BRAKE ADJUSTMENTS

Axle #	1	2	3	4	5
Right	3/4	1 1/2	1 1/4	1 1/4	1 1/4
Left	1 1/2	2 1/2	1	1 1/4	1 1/4
Chamber	C-24	C-30	C-30	C-30	C-30

VIOLATIONS

Violation Code	St	Unit	OOS	Citation #	Verify	Violations Discovered
396.3A1BA		1	N		N	Brake out of adjustment LA1
393.75(a)(1)		2	N		N	Tire-ply or belt material exposed LA4 SIDEWALL DAMAGED
393.9		1	N		N	Inoperable lamp (other than head/tail) MARKER LAMP INOP 2

**** NOTE TO DRIVER: This report must be furnished to the motor carrier whose name is listed above.

**** CARRIER CERTIFICATION: The undersigned certifies that all violations on this report have been corrected and action taken to assure compliance with the Motor Carrier Safety and HM Regulations insofar as they are applicable to motor carriers and drivers. This certification MUST BE SIGNED by the Motor Carrier and RETURNED WITHIN 15 DAYS to the address at the top of this form.

Signature of Carrier Official: X_____ Date: _____

Report Prepared By Badge #: Copy Received By:

Page #: 1
Last Page

Appendix E

Data Collection Protocol

IRISystem DATA COLLECTION PROTOCOL

Each completed inspection/screening packets must have:
1. IRISystem screening report,
2. IRISystem photographs of defects, and
3. CVSA inspection report.

1. Instructions of completion of the IRISystem Screening Report

1. **IRISystem Report #** This is a state specific report number with each state beginning with #1 and sequencing with completed vehicles. This sequence will continue for the life of the project. Each day the numbers will continue from the previous day. Example: TN001 for first inspection and continuing to increase with each inspection conducted. Include this number on the top of completed Level 1 CVSA inspection report.

2. **Operator** Show name of IRISystem operator.

3. **CVSA Inspection #** This is the number shown on the CVSA inspection form.

4. **Date/Time** Date of inspection and local time [as printed on the IRISystem photo], show EST or CST time.

5. **Location** Show roadway, mile marker location, and direction of travel of screened vehicles. If at fixed site, include name of site location.
Example: I-75 mile marker 182, southbound, SoandSo Scales

6. **Weather** Include weather conditions (Clear, cloudy, raining, foggy, snow) and average Temperature (20's, 30's, 40's...).

7. **Terrain** Show terrain type as listed in block. Example: Grade 2% to 5%.

8. **IRISystem Detectable Faults** Check box to correspond with IRISystem fault. Example Axle #1Right and Axle #4Left. See attached completed example report.

9. **Fault Types** On the line to the right of check blocks, show fault type detected. Use faults listed in block.

10. **Comments/Remarks** Only show remarks related to the IRISystem. Example: IRISystem picture not clear, foggy. Officer/originator, if different than IRISystem operator, must initial and date entries.

11. **IRISystem Checked OK** This section is for the Blind Sample Vehicles (or "Good" vehicles), vehicles showing no defects on IRISystem screening. When this box is checked, no box for the IRISystem detectable faults should be checked. (Item 8)

Select everyday, at a minimum, 1 vehicle with NO defects showing for two vehicles with defects (1 out of 3 total number of vehicles inspected, 2 out of 6, 3 out of 9, etc...). The inspector must not be told this is a non-defect vehicle.

12. On the back on the IRISystem screening report, show the inspection location with reference to IRISystem setup, roadway, direction of travel of screened vehicles(use arrow), estimated speed at time of screening, estimated distance from IRISystem to screened vehicles, and Level 1 inspection location.. See completed screening report. This is completed for each set-up and is entered on the first inspection for that location. Multi-inspection at the same location should show Date and Inspection TN001-TN012 at this setup location. When changing location, complete a new diagram.

2. Instructions for the IRISystem Photographs

A photo is included in the example report

1. Photographs must be attached to all inspection packets.

2. The Photograph must show the correct date and time of inspection (same as on IRISystem screening report).

3. CIRCLE all defects detected by the IRISystem (Use Sharpy-type pen).
   Make sure that the defects circled match IRISystem detectable faults shown on the IRISystem report.
   If several defects are detected (see example report), then all defects must be documented by a photo. If necessary, include more than one photo.

4. Indicate the vehicle direction with an arrow (use Sharpy-pen)

5. On the back of the photograph, show the CVSA inspection number and the state specific inspection number. Example: TN0002345, TN001.

3. Instructions for the CVSA Level 1 inspections

Complete CVSA Level 1 inspection as usual.

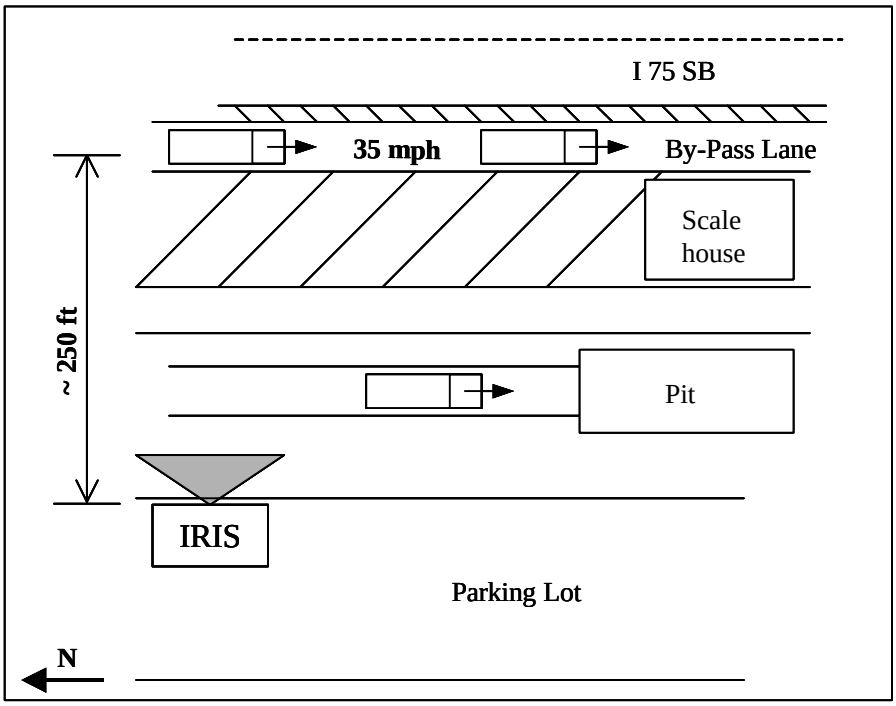
1. On the CVSA Level 1 Inspection Report, Circle the following (see example):
   a. CVSA inspection number
   b. Cargo
   c. Misadjusted brakes
   d. OOS: Yes or No

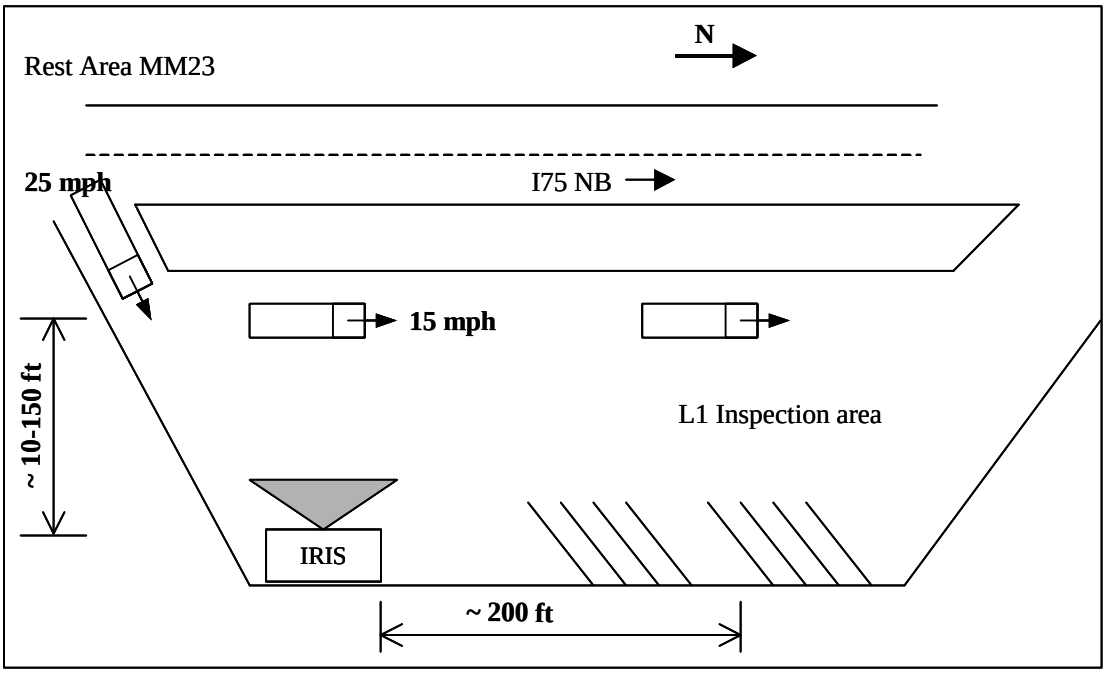
2. Include the IRISystem report number (TN001) on the top of completed Level 1 CVSA inspection report.

Appendix F

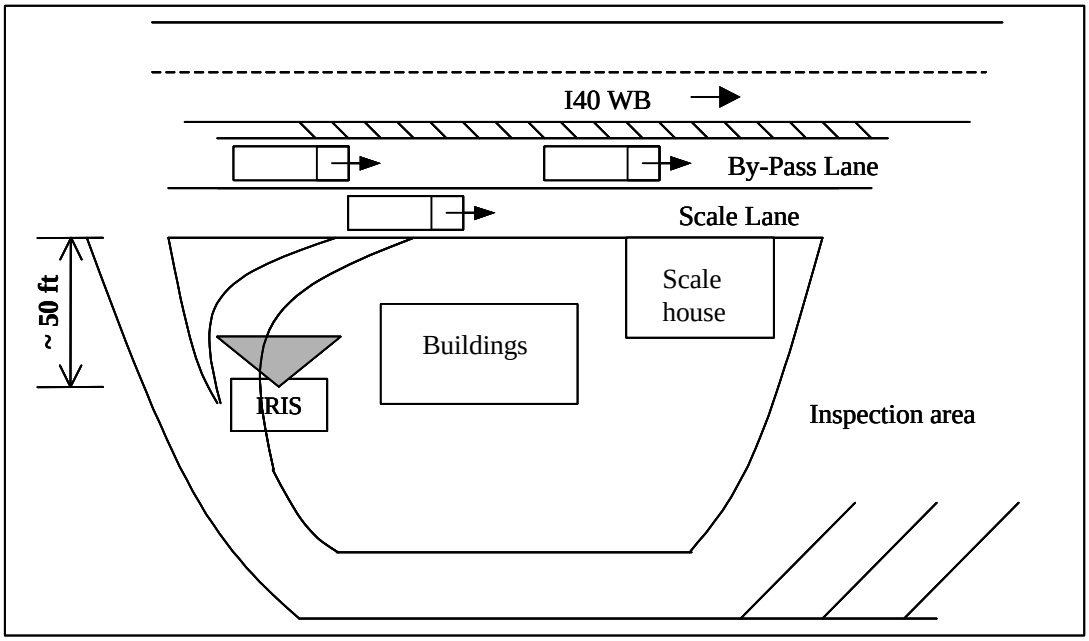
IRISystem Setup Drawings

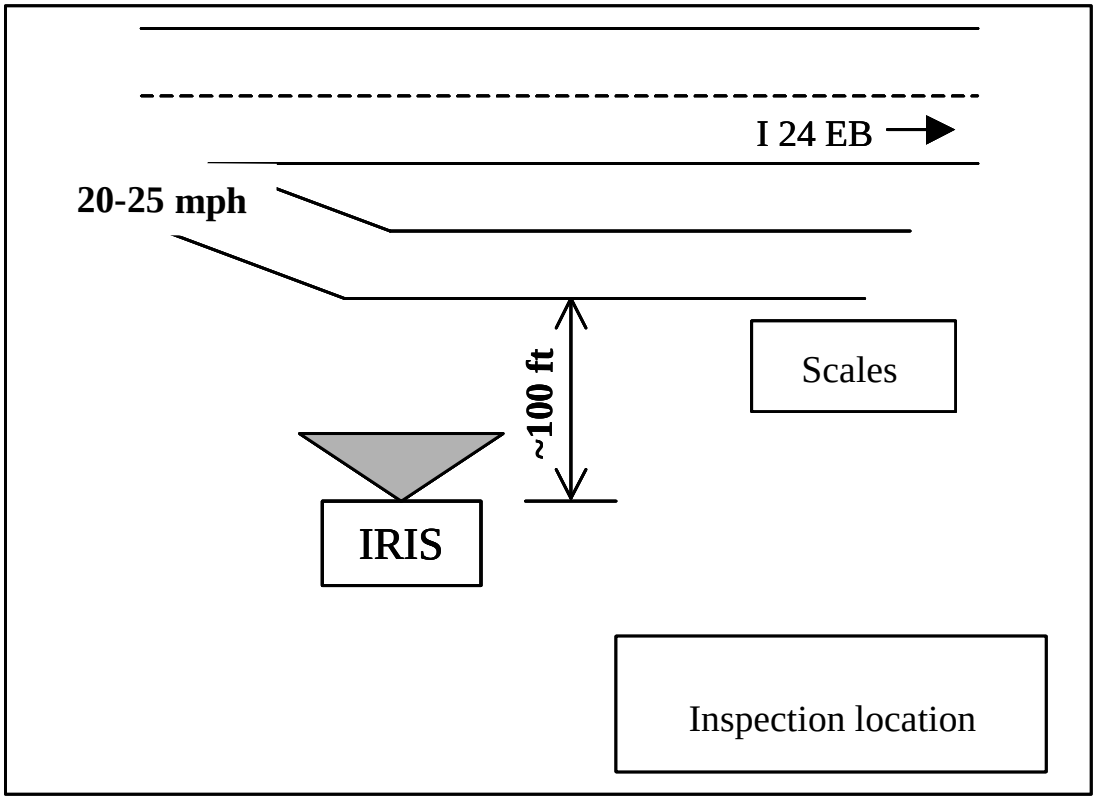
Location of IRISystem Screening:
At weigh station facilities



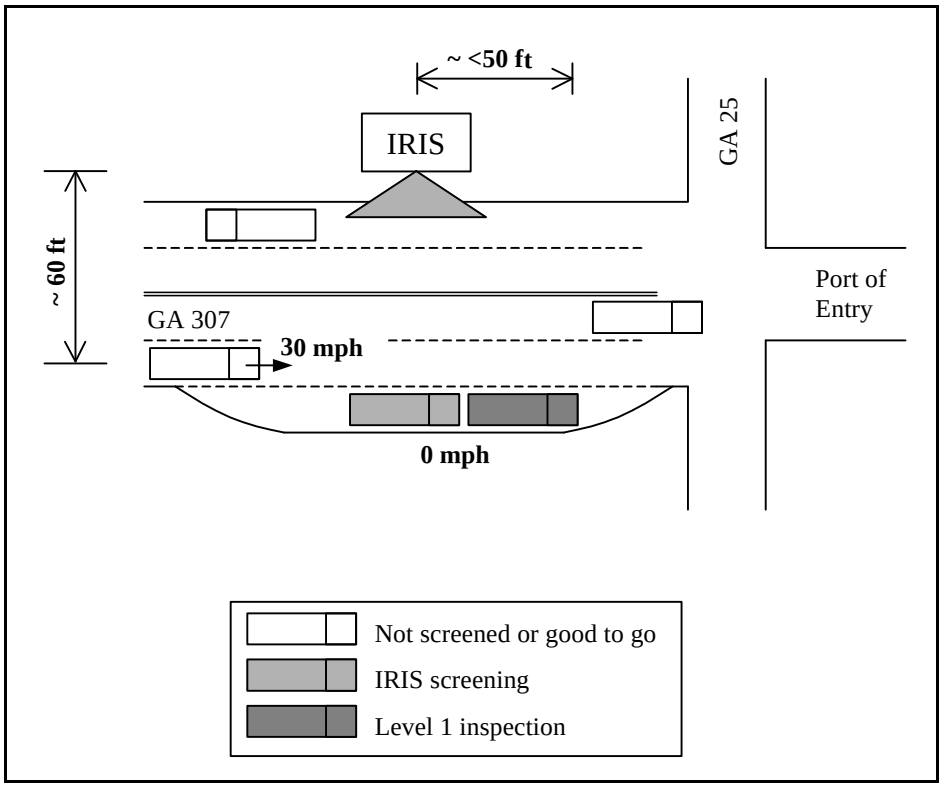


Location of IRISystem Screening:
At weigh station facilities (Continued)

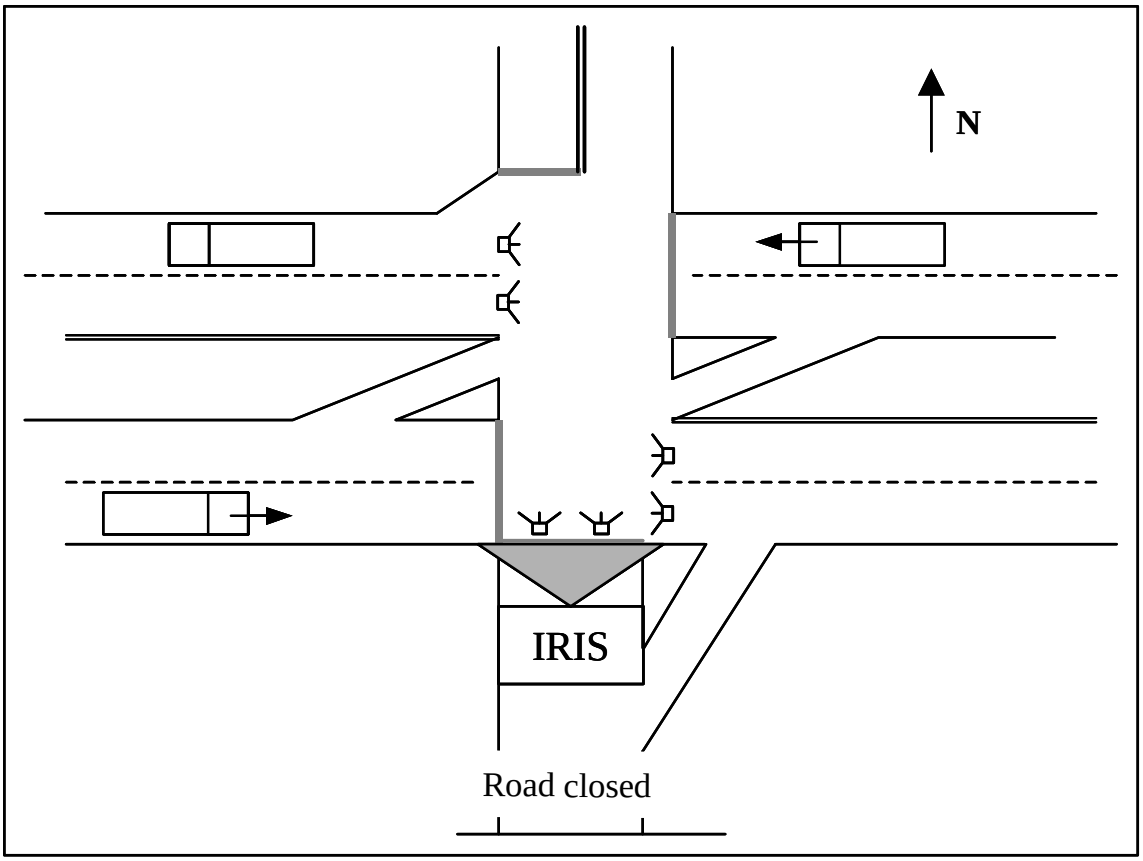




Location of IRISystem Screening:
Near a port of entry in Georgia



Location of IRISystem Screening:
On Georgia State roads



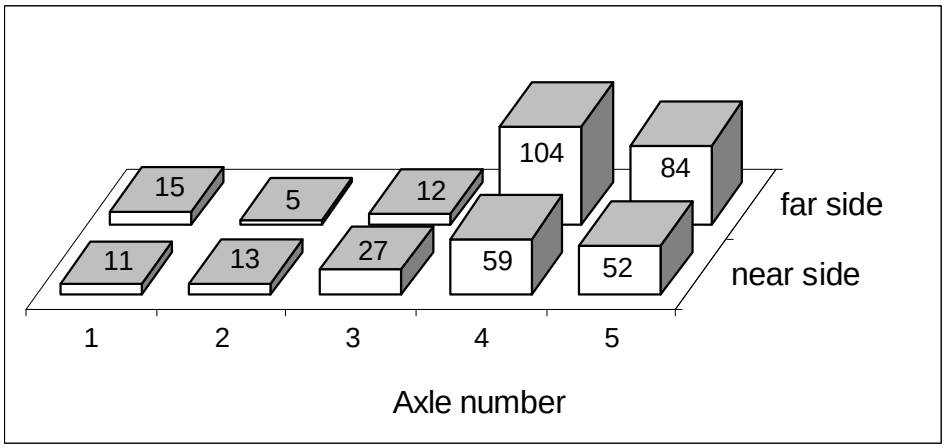
Appendix G

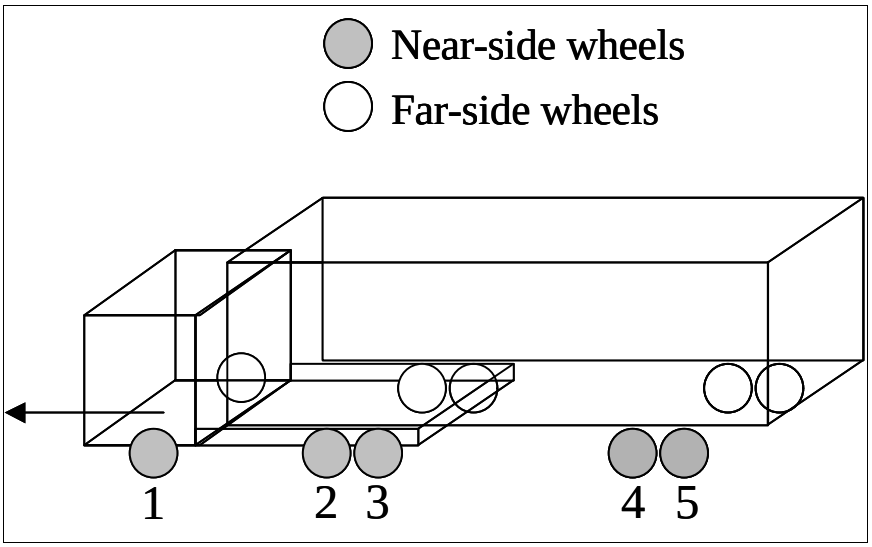
Results

Location of Problematic Wheels Identified by the IRISystem operator Out Of Service Vehicles

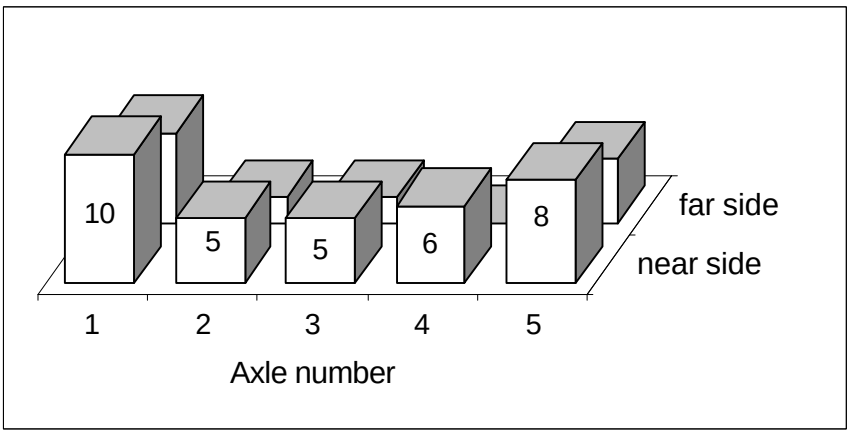
All States

Number of problematic wheels identified by IRISystem as a function of wheel location on a 3-S2 CMV. The data are for all states. The arrow indicates the direction of the vehicle. The schematic illustrates the near-side and far-side wheel location as well as the axle numbers.

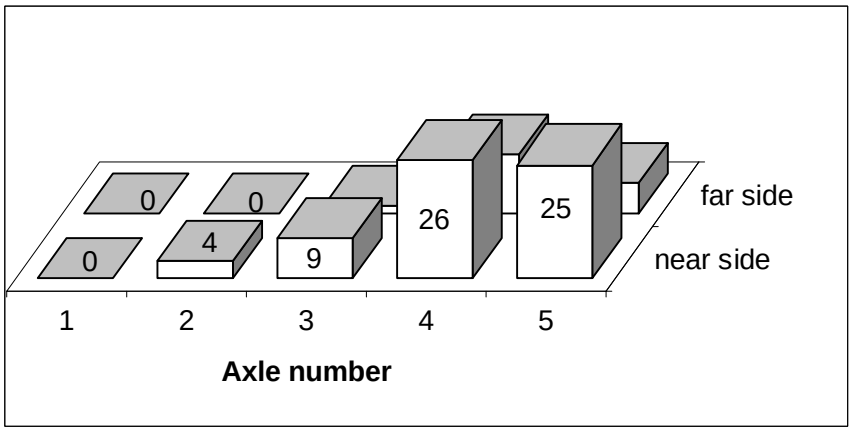




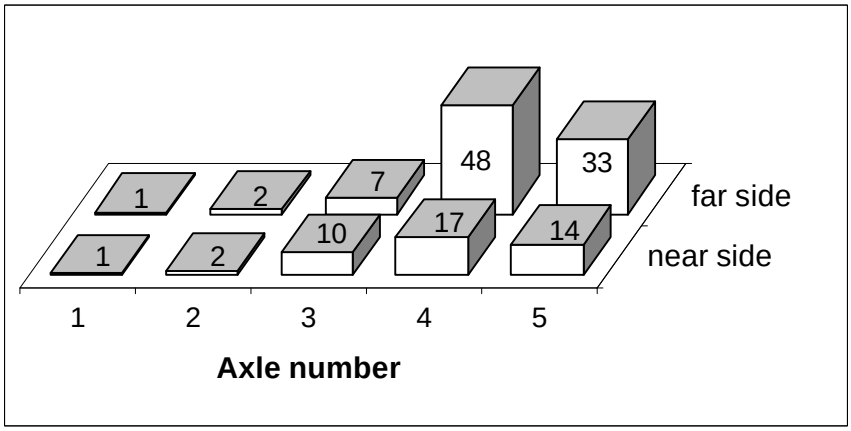
Georgia



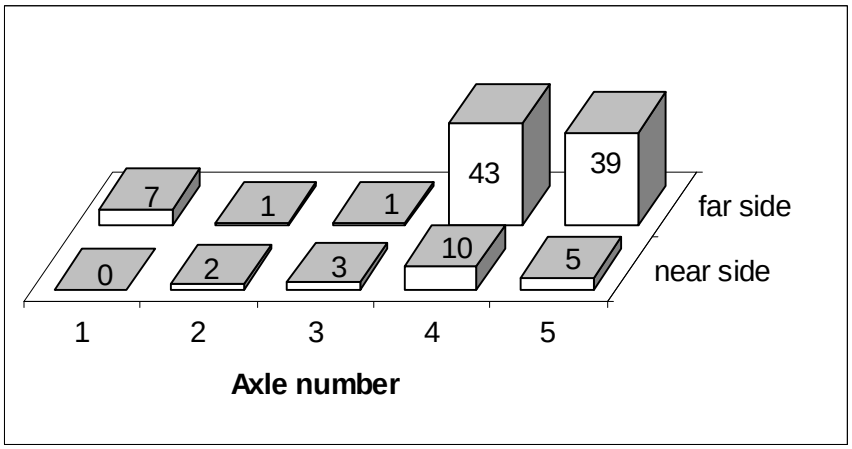
Kentucky



North Carolina



Tennessee



Appendix H

Results

Number of CVSA-Identified FMCSR Violations as a Function of IRIS-Identified Problematic Wheels

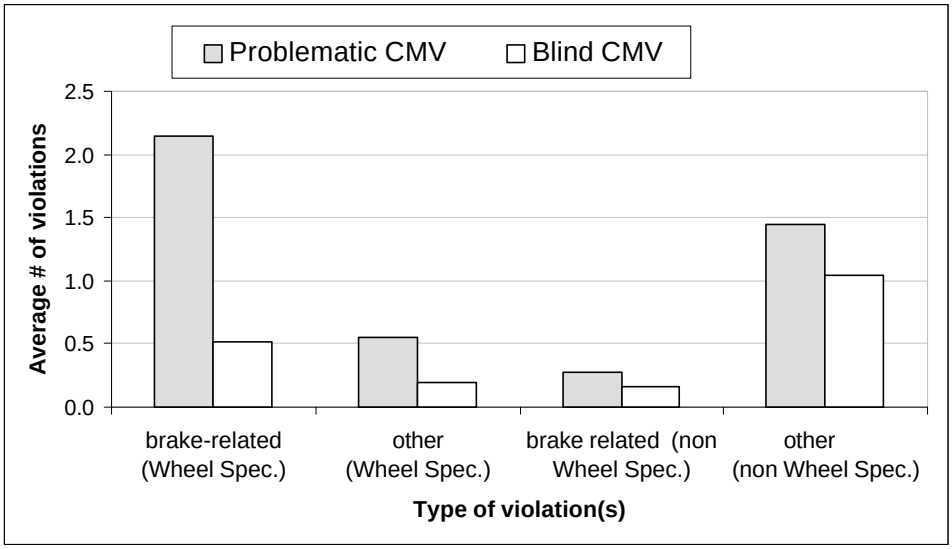
Table H-1. Summary of data collected.

	All	GA	KY	NC	TN
Number of CMVs inspected	392	39	104	130	119
Percentage of blind, non-problematic, CMVs	*16%*	*15%*	*8%*	*15%*	*24%*
Percentage of 3-S2 CMVs	*88%*	*82%*	*79%*	*87%*	*97%*
Percentage of loaded 3-S2 CMVs	*70%*	*59%*	*81%*	*68%*	*66%*
Number of days in use (for evaluation	77	10	12	23	32
Percentage of problematic (cold) wheels ††	*11%*	*17%*	*9%*	*11%*	*9%*
Percentage of problematic (hot) wheels ††	*1%*	--	*2%*	*1%*	*<1%*
Average # of IRIS-identified problems per 3-S2	1.3	1.9	1.1	1.4	1.2

† These numbers only reflect the usable data reports. †† As identified by the IRISystem operator.

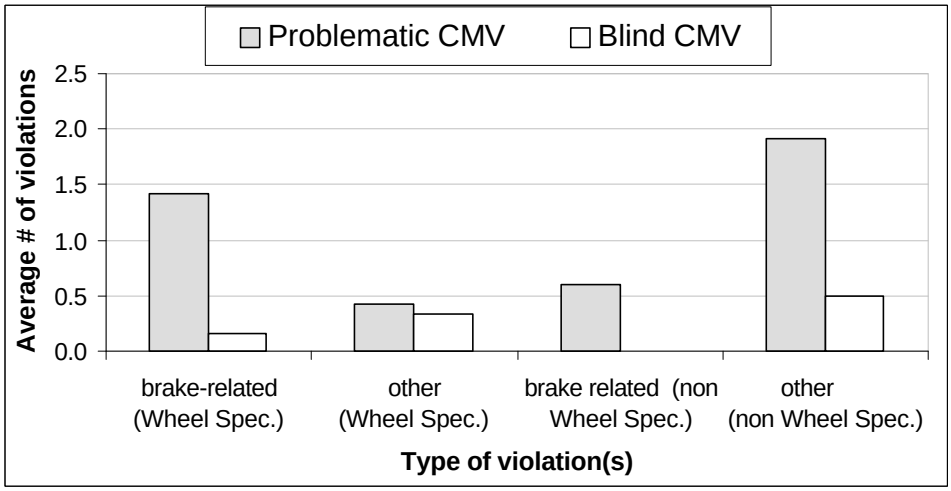
All States

Figure H-1. Average number of FMCSR violations reported in L1 inspections for CMVs screened with the IRISystem.



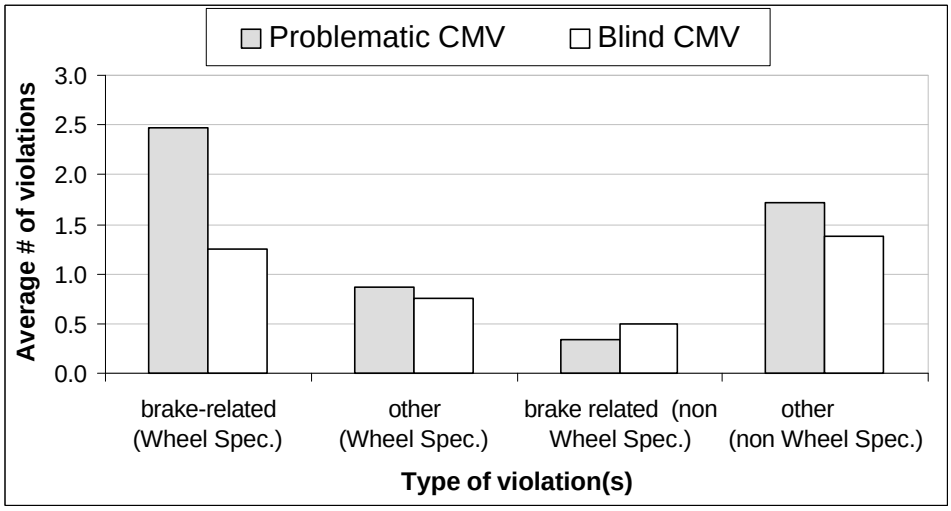
Georgia

Figure H-2. Average number of FMCSR violations reported in L1 inspections for CMVs screened with the IRISystem.



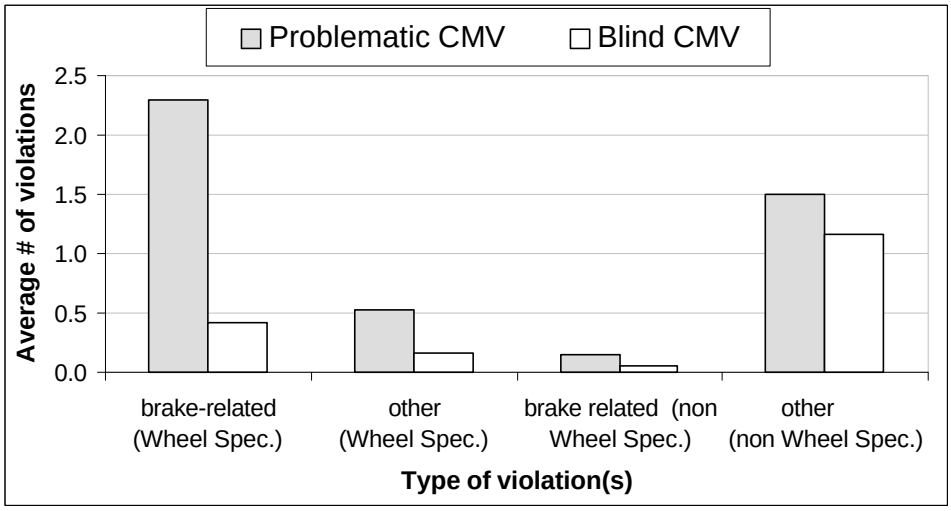
Kentucky

Figure H-3. Average number of FMCSR violations reported in L1 inspections for CMVs screened with the IRISystem.



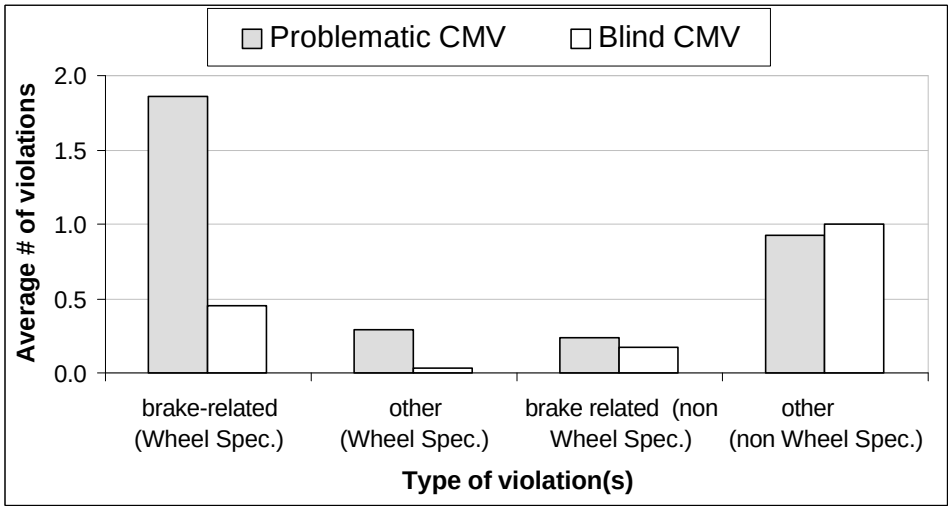
North Carolina

Figure H-4. Average number of FMCSR violations reported in L1 inspections for CMVs screened with the IRISystem.



Tennessee

Figure H-5. Average number of FMCSR violations reported in L1 inspections for CMVs screened with the IRISystem.



Appendix I

Results

Wheel-by-Wheel Analysis

Table I-1. Percentage agreement between the IRISystem screening results and the Level 1 inspection results per state and per type of IRIS-identified wheel.

IRISystem diagnostic		All States	GA	KY	NC	TN
Normal wheels	# of wheels (% total)	3326 (88%)	301 (83%)	884 (88%)	1076 (88%)	1065 (90%)
	% agreement †	***85%***	***92%***	***79%***	***86%***	***88%***
Cold Wheels	# of wheels (% total)	399 (11%)	61 (17%)	94 (9%)	134 (11%)	110 (9%)
	% agreement †, 1	***68%***	***59%***	***68%***	***84%***	***55%***
	% agreement †, 2	***76%***	***81%***	***73%***	***85%***	***65%***
Hot Wheels	# of wheels (% total)	44 (1%)	0	24 (2%)	15 (1%)	5 (<1%)
	% agreement †	***68%***	***n/a***	***71%***	***67%***	***60%***
Total # wheels		3769	362	1002	1225	1180

† Between IRISystem screening results and Level 1 inspection results

1 Level 1 inspection identified one or more wheel-specific defect, whether brake-related or not (Table 4).

2 Level 1 inspection identified one or more brake-related defect, whether wheel-specific or not (Table 4).

All States

Figure I-1. Percentage of agreement between the IRISystem screening results and the Level 1 inspection results as a function of IRISystem wheel diagnostic. "Cold 1" and "Cold 2" refer to two different comparisons, with wheel-specific violations and brake-related violations, respectively.

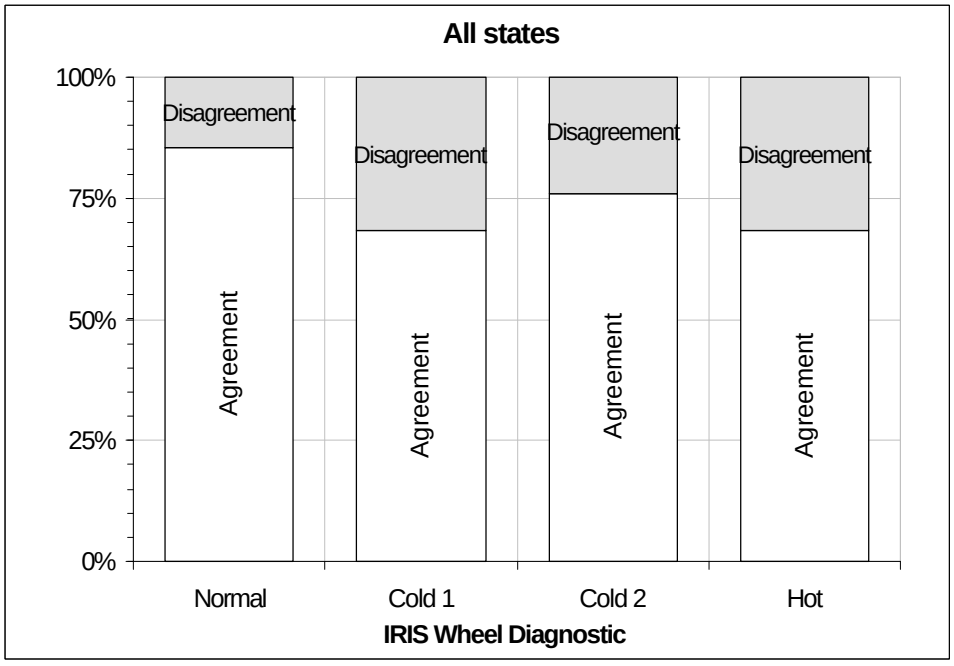


Figure I-2. Percentage of agreement between the IRISystem screening results and the Level 1 inspection results as a function of IRISystem wheel diagnostic. "Cold 1" and "Cold 2" refer to two different comparisons, with wheel-specific violations and brake-related violations, respectively.

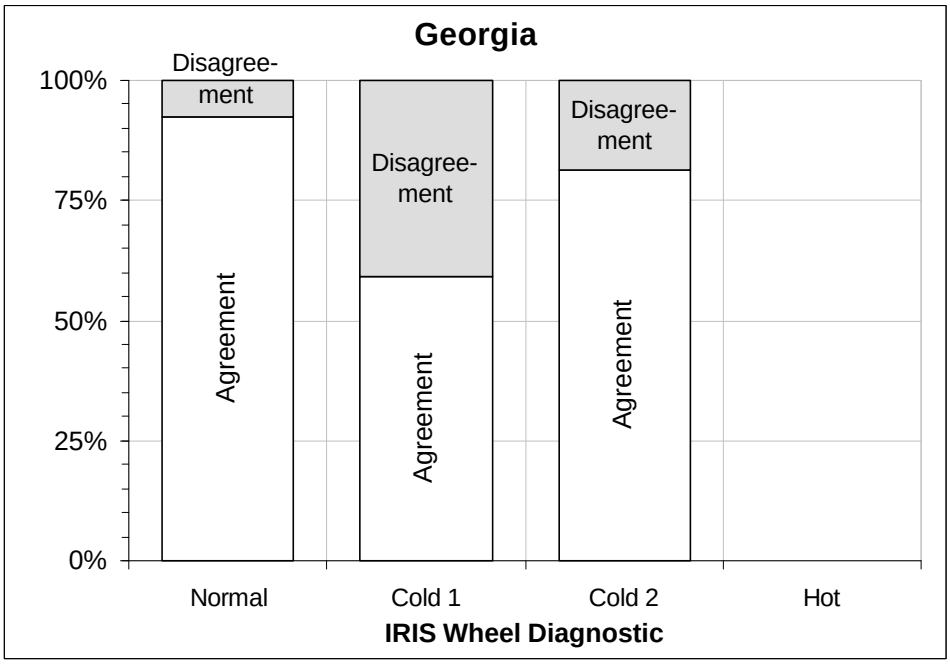


Figure I-3. Percentage of agreement between the IRISystem screening results and the Level 1 inspection results as a function of IRISystem wheel diagnostic. "Cold 1" and "Cold 2" refer to two different comparisons, with wheel-specific violations and brake-related violations, respectively.

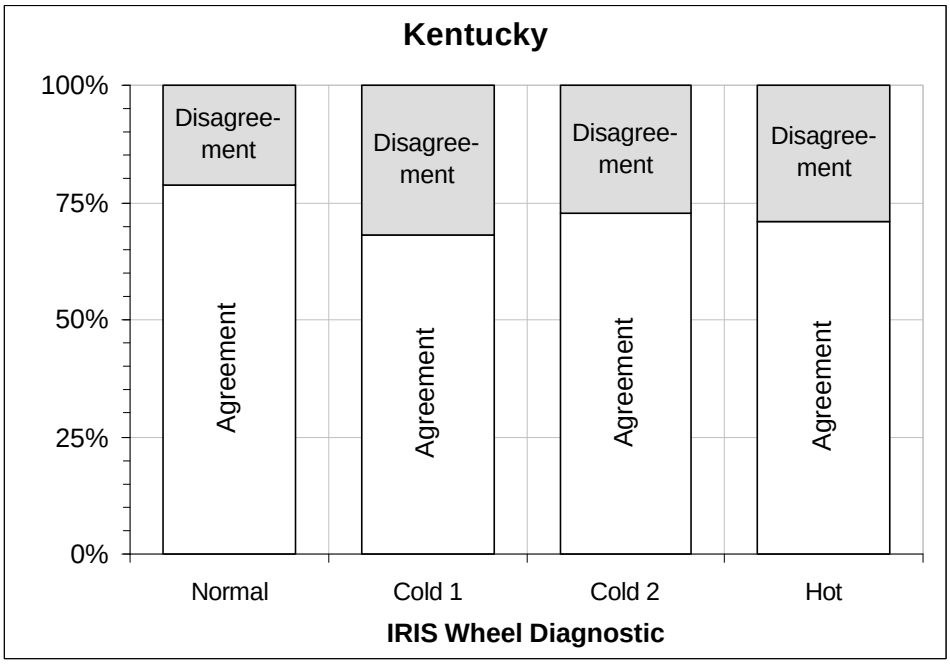


Figure I-4. Percentage of agreement between the IRISystem screening results and the Level 1 inspection results as a function of IRISystem wheel diagnostic. "Cold 1" and "Cold 2" refer to two different comparisons, with wheel-specific violations and brake-related violations, respectively.

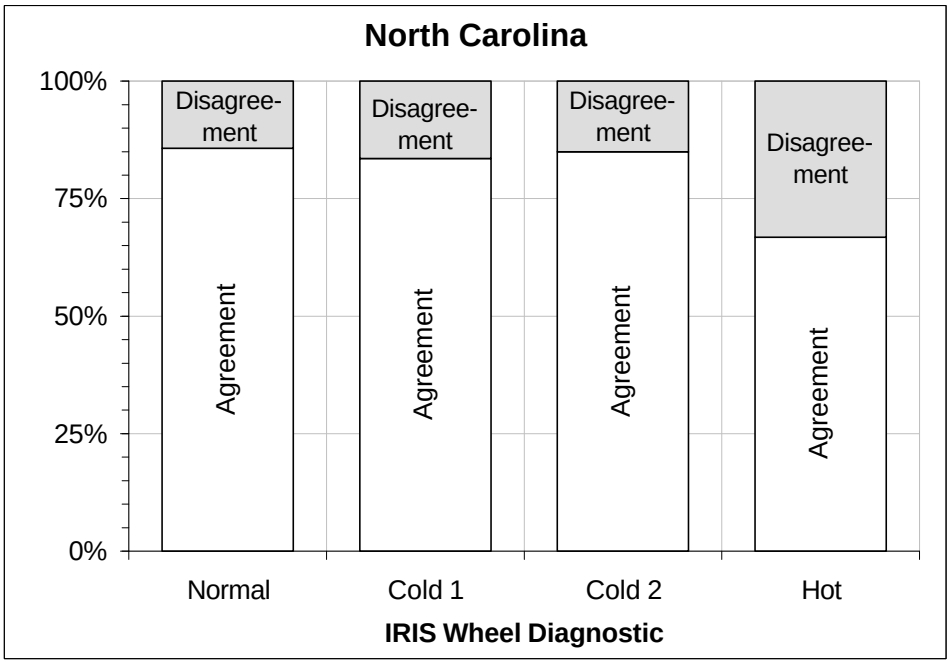
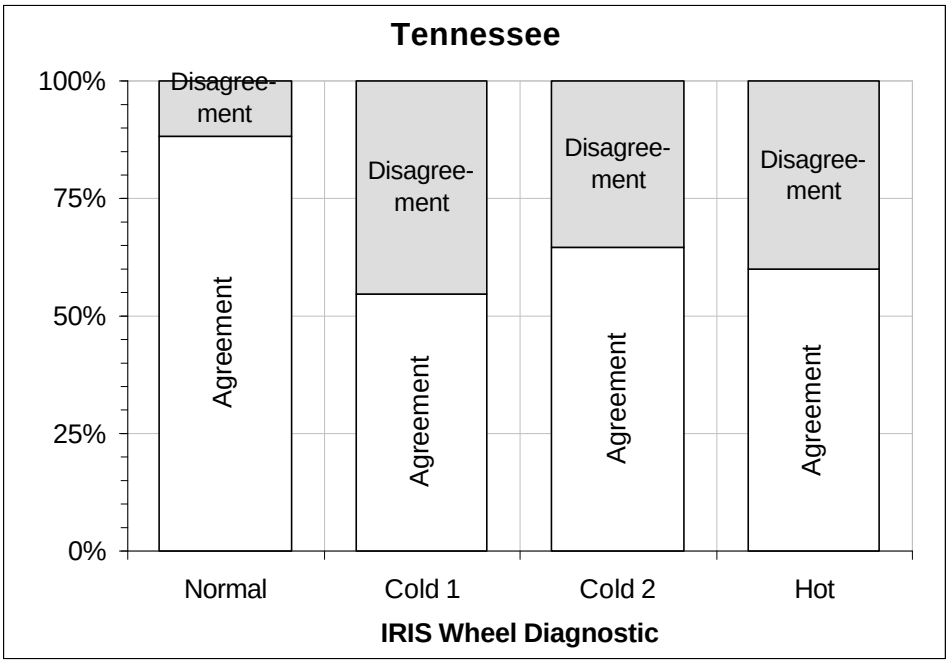


Figure I-5. Percentage of agreement between the IRISystem screening results and the Level 1 inspection results as a function of IRISystem wheel diagnostic. "Cold 1" and "Cold 2" refer to two different comparisons, with wheel-specific violations and brake-related violations, respectively.



Appendix J

Results

Out Of Service (OOS) Vehicles

Table J-1. Percentage of CMVs placed OOS after IRISystem screening

	Not placed OOS	Placed OOS			
		Any criteria	*Brake violation(s) only* ††	*Brake and other violation(s)* ††	*Other-than-brake violation(s)* ††
All CMVs (392)	47%	53%	*57%*	*21%*	*22%*
Blind, non-problematic, CMVs (62)	81%	19%	*58%*	*8%*	*33%*
Problem. CMVs (330)	41%	59%	*57%*	*22%*	*21%*
GA (33) †	45%	55%	*67%*	*17%*	*17%*
KY (96) †	47%	53%	*55%*	*20%*	*25%*
NC (111) †	33%	67%	*54%*	*27%*	*19%*
TN (90) †	43%	57%	*61%*	*18%*	*22%*

† Problematic vehicles only. †† Percentage of OOS vehicles only.

All States

Figure J-1. Percentage of CMV placed out of service in all four states after IRISystem screening detected problematic wheels.

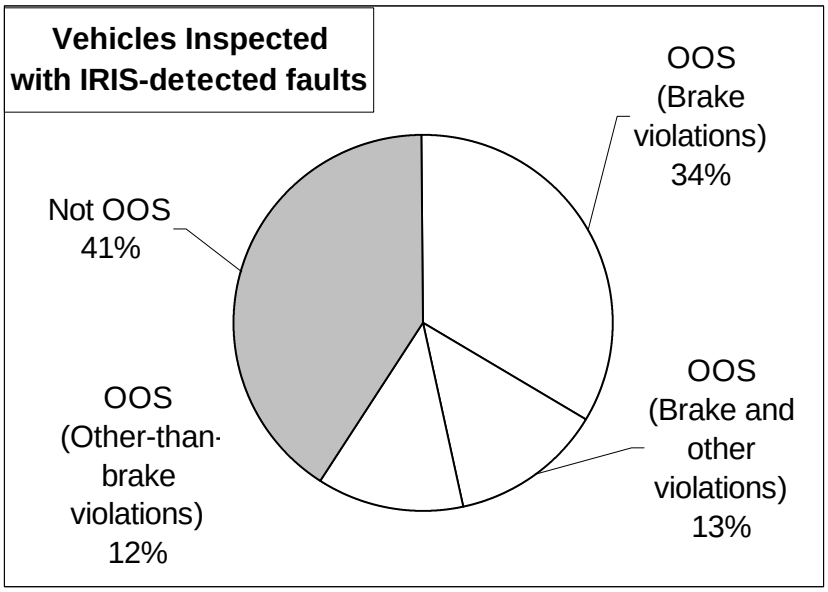
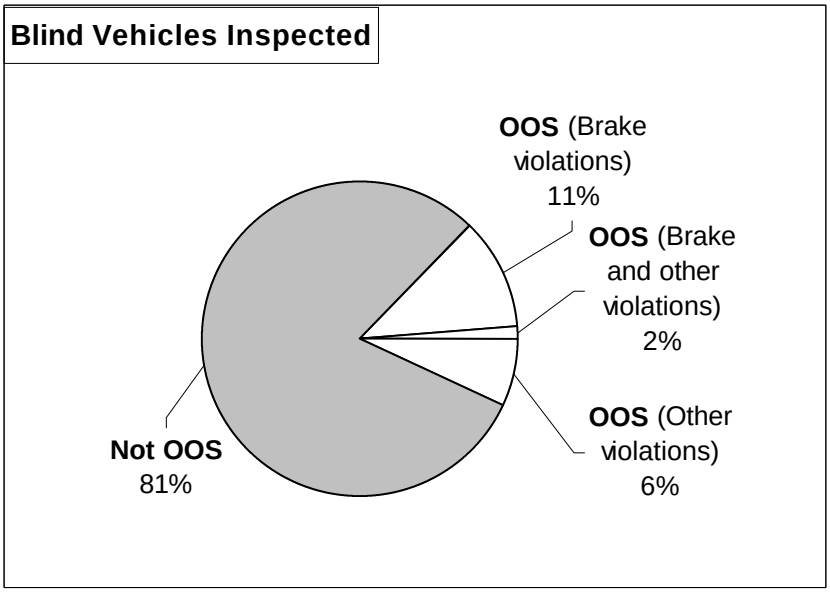


Figure J-2. Percentage of CMV placed out of service in all four states after IRISystem screening DID NOT detect problematic wheels (blind vehicles).



Georgia

Figure J-3. Percentage of CMV placed out of service in Georgia after IRISystem screening detected problematic wheels.

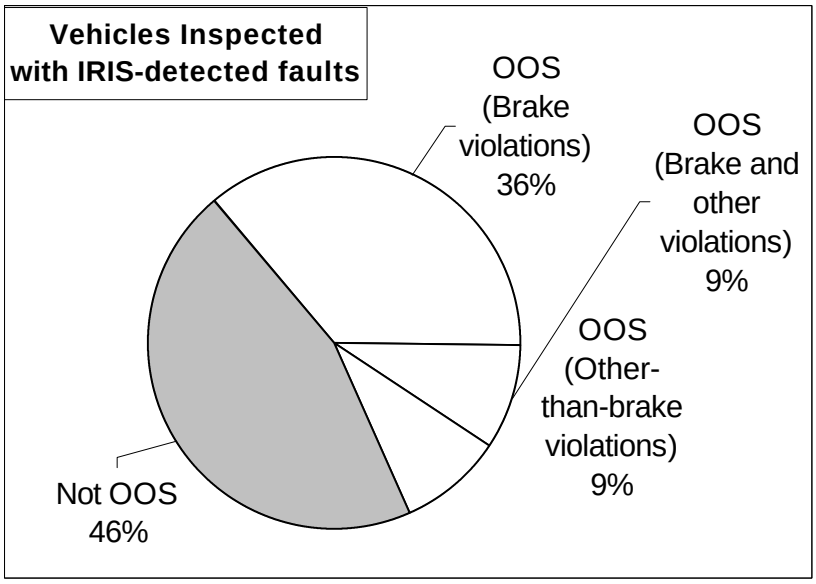


Figure J-4. Percentage of CMV placed out of service in Georgia after IRISystem screening DID NOT detect problematic wheels (blind vehicles).

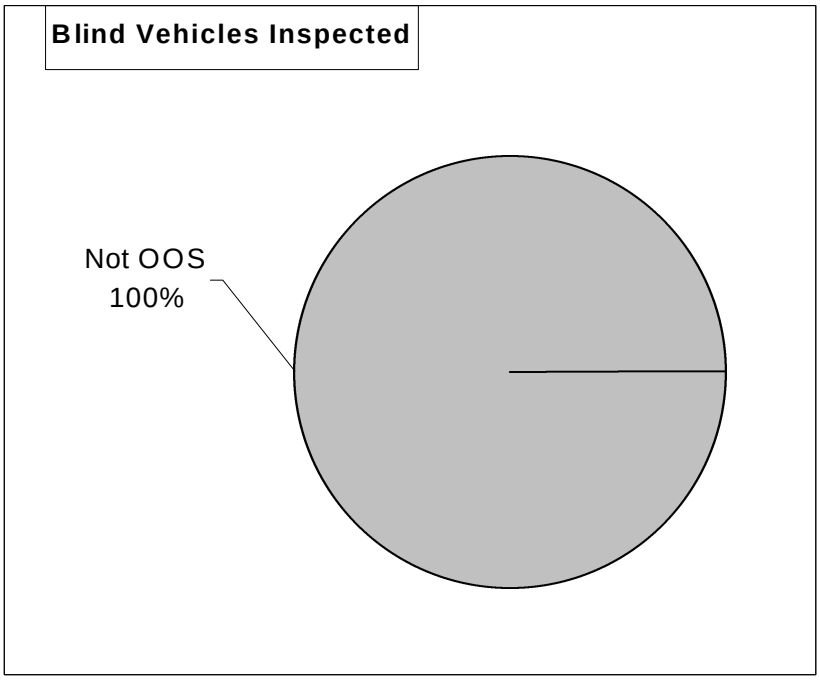


Figure J-5. Percentage of CMV placed out of service in Kentucky after IRISystem screening detected problematic wheels.

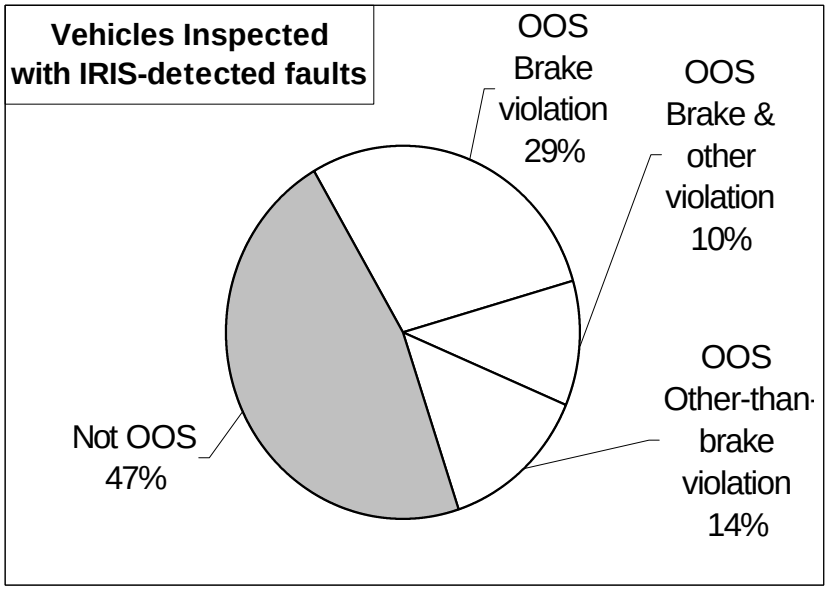
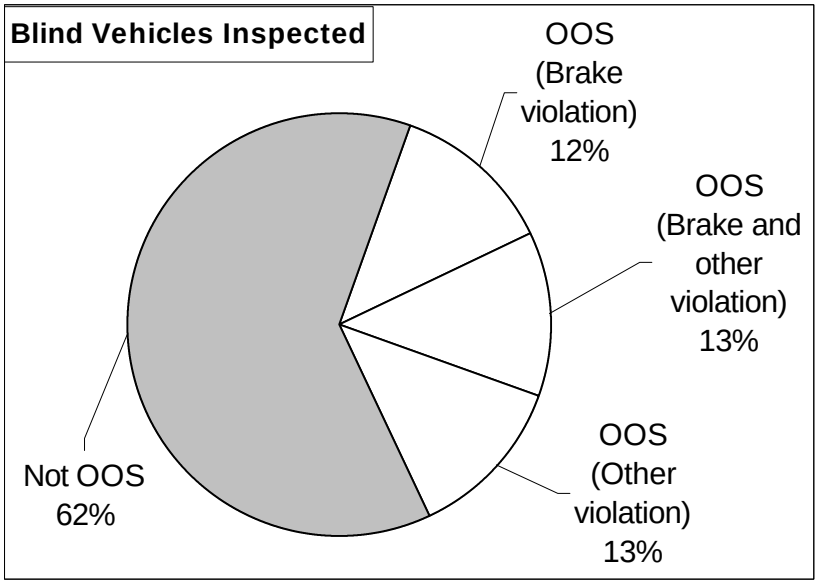


Figure J-6. Percentage of CMV placed out of service in Kentucky after IRISystem screening DID NOT detect problematic wheels (blind vehicles).



North Carolina

Figure J-7. Percentage of CMV placed out of service in North Carolina after IRISystem screening detected problematic wheels.

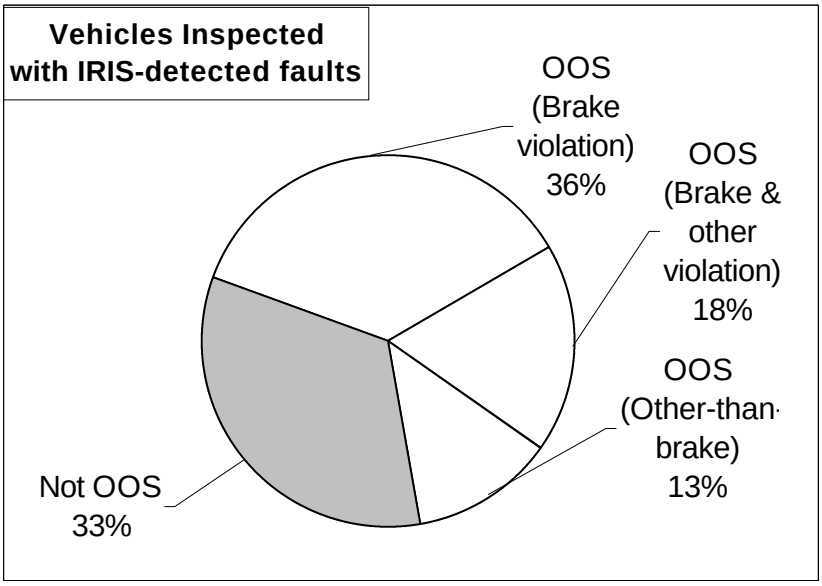
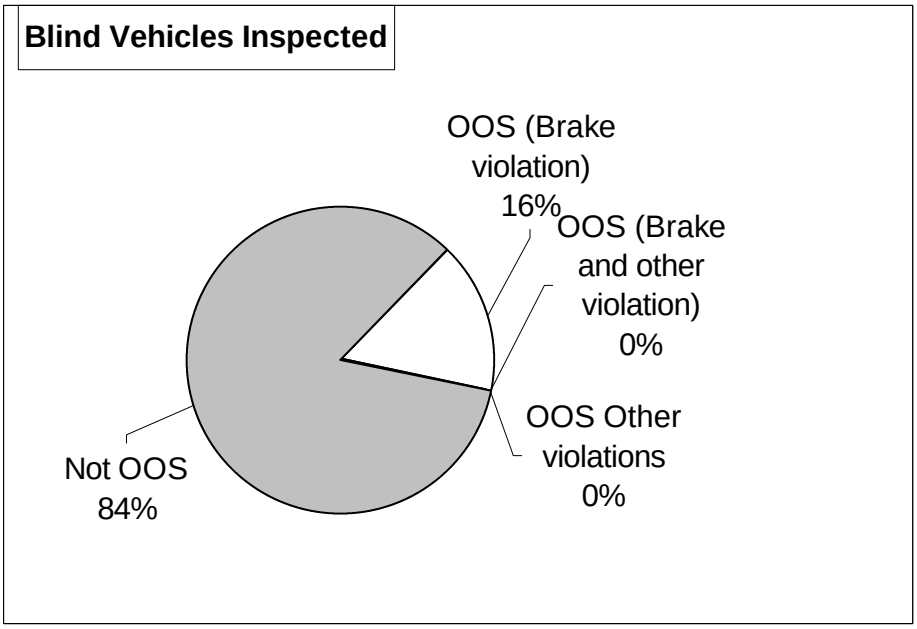


Figure J-8. Percentage of CMV placed out of service in North Carolina after IRISystem screening DID NOT detect problematic wheels (blind vehicles).



Tennessee

Figure J-9. Percentage of CMV placed out of service in Tennessee after IRISystem screening detected problematic wheels.

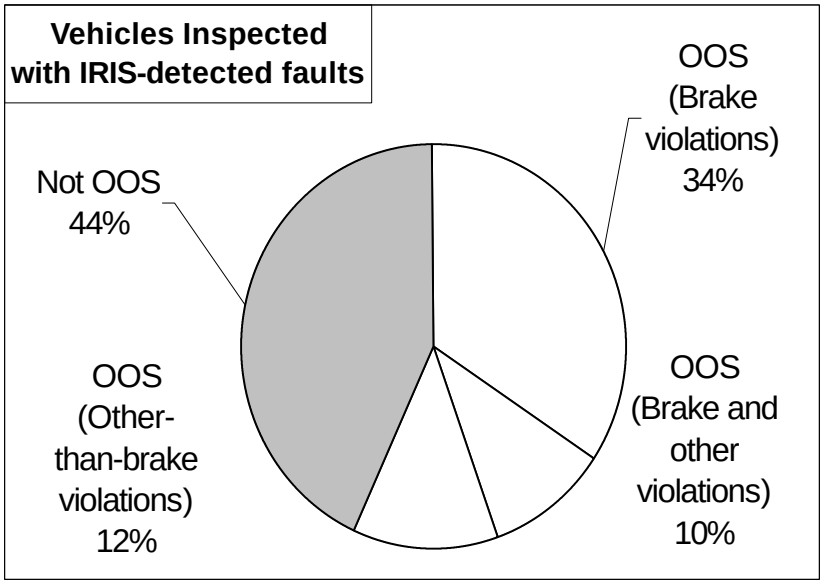


Figure J-10. Percentage of CMV placed out of service in Tennessee after IRISystem screening DID NOT detect problematic wheels (blind vehicles).

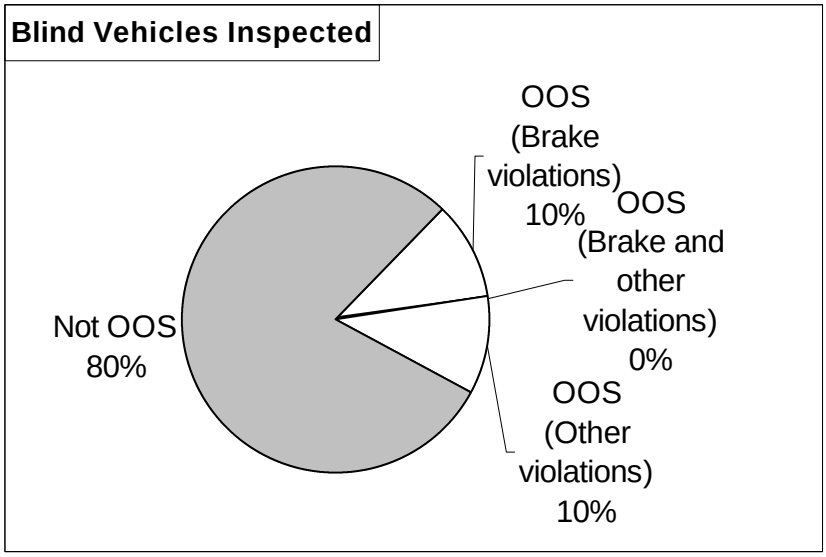
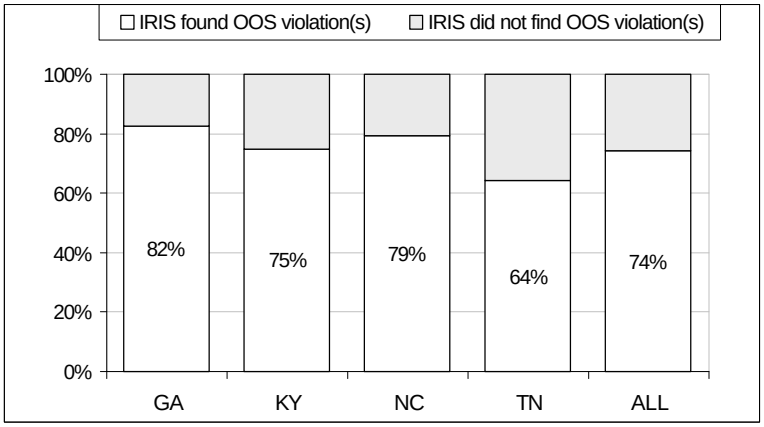


Figure J-11. Percentage of OOS CMVs for which the IRISystem found or did not find the OOS violation(s).



Appendix K

Results

Comparison with SAFETYNET data

Table K-1. Percentage of OOS, BV and OOS with BV after IRISystem Screening (for problematic CMVs only) and after current screening (SAFETYNET Level 1 inspections data for 1997-1999). The numbers indicated in parenthesis indicate the ratio of IRISystem over current screening results.

	Screening method	Number of CMV	OOS	BV †	OOS & BV †
All States	Current	216865	27%	34%	15%
	IRISystem††	330	59% (2.2)	84% (2.5)	52% (3.4)
GA	Current	23317	41%	37%	23%
	IRISystem††	33	55% (1.3)	82% (2.2)	48% (2.1)
KY	Current	104256	19%	37%	11%
	IRISystem††	96	53% (2.9)	85% (2.3)	45% (4.0)
NC	Current	32645	30%	32%	19%
	IRISystem††	111	67% (2.2)	88% (2.8)	60% (3.2)
TN	Current	56647	35%	28%	18%
	IRISystem††	90	57% (1.6)	79% (2.8)	52% (2.9)

† BV: Brake violation(s), not necessarily resulting in OOS. †† Problematic vehicles only.

Figure K-1. All States

Top plot **Percentage of CMV placed OOS for all four states after IRISystem screening (no blind vehicles) and after current screening (SAFETYNET data, for 1997-1999 and Level 1 inspections).**

Bottom plot **Same as top plot, but showing SAFETYNET data per year.**

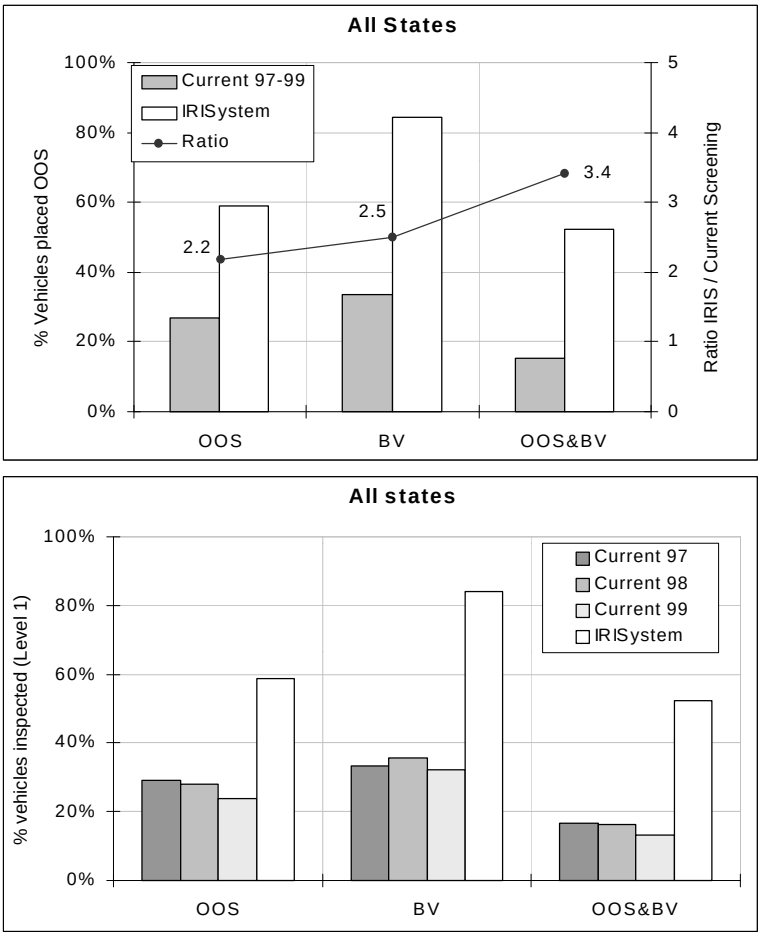
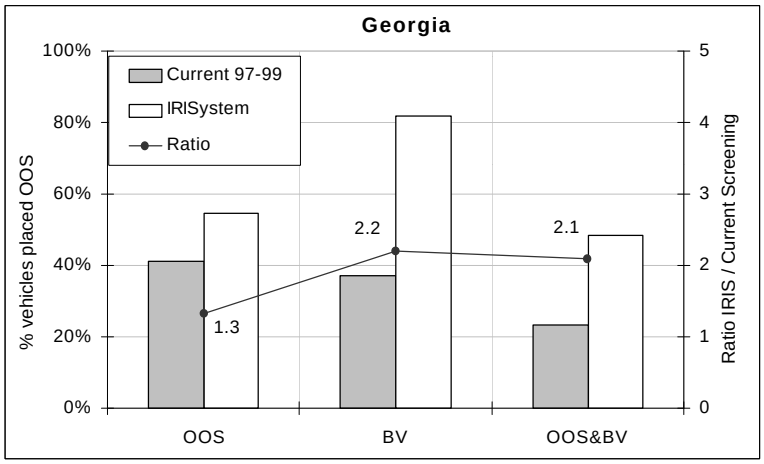


Figure K-2. Georgia

Top plot **Percentage of CMV placed OOS for Georgia after IRISystem screening (no blind vehicles) and after current screening (SAFETYNET data, for 1997-1999 and Level 1 inspections).**

Bottom plot **Same as top plot, but showing SAFETYNET data per year.**



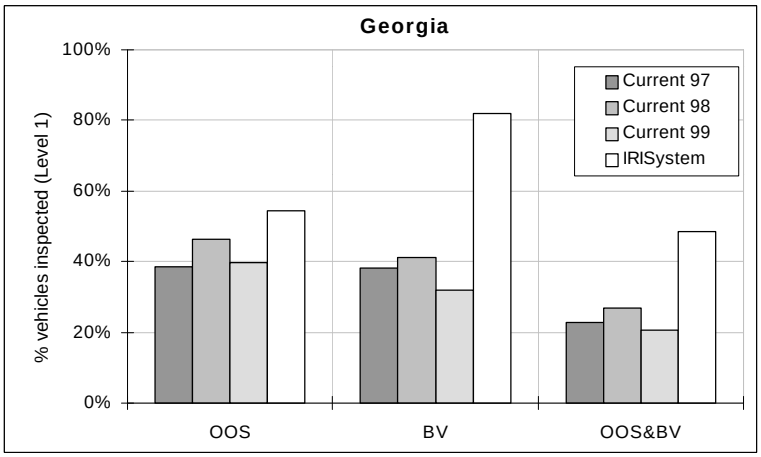


Figure K-3. Kentucky

Top plot **Percentage of CMV placed OOS for Kentucky after IRISystem screening (no blind vehicles) and after current screening (SAFETYNET data, for 1997-1999 and Level 1 inspections).**

Bottom plot **Same as top plot, but showing SAFETYNET data per year.**

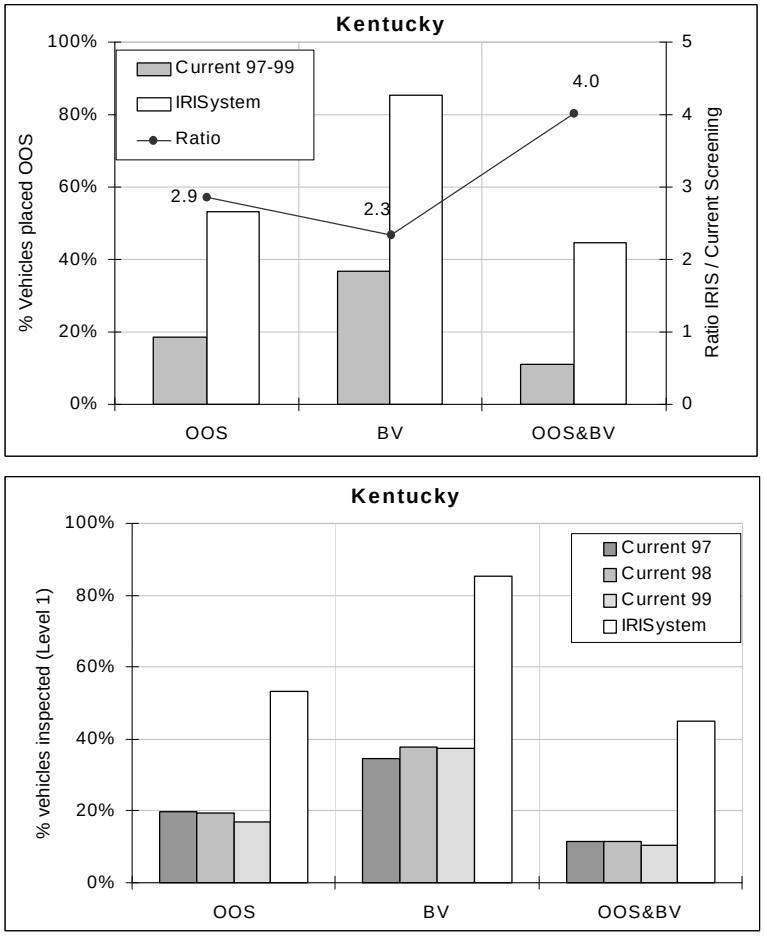


Figure K-4. North Carolina

Top plot **Percentage of CMV placed OOS for North Caroline after IRISystem screening (no blind vehicles) and after current screening (SAFETYNET data, for 1997-1999 and Level 1 inspections).**

Bottom plot **Same as top plot, but showing SAFETYNET data per year.**

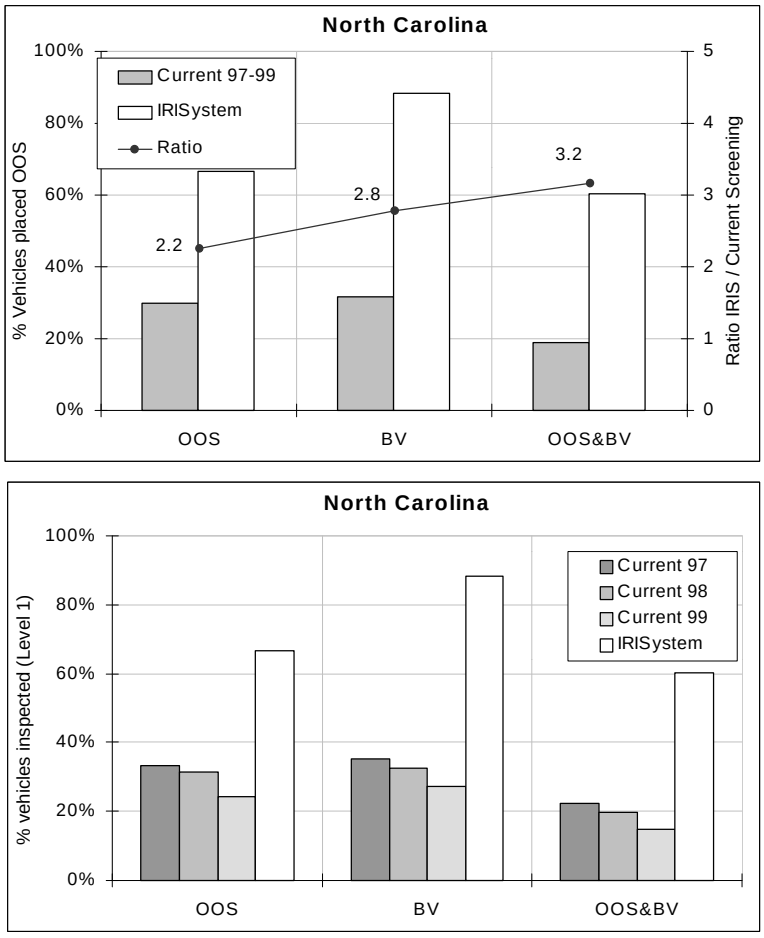


Figure K-5. Tennessee

Top plot **Percentage of CMV placed OOS for Tennessee after IRISystem screening (no blind vehicles) and after current screening (SAFETYNET data, for 1997-1999 and Level 1 inspections).**

Bottom plot **Same as top plot, but showing SAFETYNET data per year.**