

Inward- and Outward-facing Audio and Video Recordings for Transit Rail Vehicles

AUGUST 2021

FTA Report No. 0200
Federal Transit Administration

PREPARED BY

MaryClara Jones
Travis Gorham

Transportation
Technology Center, Inc.
A subsidiary of the
Association of
American Railroads



COVER PHOTO

Courtesy of Bay Area Regional Transit (BART)

DISCLAIMER

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof. The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report. The opinions and/or recommendations expressed herein do not necessarily reflect those of the U.S. Department of Transportation.

Inward- and Outward-Facing Audio and Video Recordings for Transit Rail Vehicles

AUGUST 2021

FTA Report No. 0200

PREPARED BY

MaryClara Jones

Travis Gorham

Transportation Technology Center, Inc.

A subsidiary of the Association of American Railroads

55500 DOT Road

Pueblo, CO 81001

SPONSORED BY

Federal Transit Administration

Office of Research, Demonstration and Innovation

U.S. Department of Transportation

1200 New Jersey Avenue, SE

Washington, DC 20590

AVAILABLE ONLINE

<https://www.transit.dot.gov/about/research-innovation>

Metric Conversion Table

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liter	L
ft³	cubic feet	0.028	cubic meters	m ³
yd³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188		
<p>The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p>					
1. REPORT DATE August 2021		2. REPORT TYPE Final		3. DATES COVERED April 2018–April 2021	
4. TITLE AND SUBTITLE Inward- and Outward-Facing Audio and Video Recordings for Transit Rail Vehicles			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) MaryClara Jones, Travis Gorham			5d. PROGRAM NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Transportation Technology Center, Inc. (TTCI) A subsidiary of the Association of American Railroads 55500 DOT Road, Pueblo, CO 81001			8. PERFORMING ORGANIZATION REPORT NUMBER FTA Report No. 0200		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Transit Administration Office of Research, Demonstration and Innovation 1200 New Jersey Avenue, SE, Washington, DC 20590			10. SPONSOR/MONITOR'S ACRONYM(S) FTA		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT Available from: National Technical Information Service (NTIS), Springfield, VA 22161; (703) 605-6000, Fax (703) 605-6900, email [orders@ntis.gov]; Distribution Code TRI-30					
13. SUPPLEMENTARY NOTES [www.transit.dot.gov/research-innovation/fta-reports-and-publications] [https://www.transit.dot.gov/about/research-innovation] [https://doi.org/10.21949/1520686] Suggested citation: Federal Transit Administration. Inward- and Outward-Facing Audio and Video Recordings for Transit Rail Vehicles. Washington, D.C.: United States Department of Transportation, 2021. https://doi.org/10.21949/1520686.					
14. ABSTRACT <p>The National Transportation Safety Board (NTSB) has investigated numerous railroad and rail transit accidents for which inward- and outward-facing camera and audio recorders provided or could have provided an unequivocal record of a train operator's actions. Recognizing the importance of this technology, the Fixing America's Surface Transportation (FAST) Act of 2015 mandated that the Federal Railroad Administration (FRA) issue regulations requiring video recorders. The mandate also gave the Secretary of Transportation the discretion to require audio recordings on all FRA-regulated passenger (intercity and commuter) trains operating on the general railroad system. As a result of additional events and ongoing investigations, including the collision of two Southeastern Pennsylvania Transportation Authority (SEPTA) trains in Upper Darby, Pennsylvania, on February 21, 2017, the NTSB issued one safety recommendation to FTA and two to SEPTA associated with inward- and outward-facing cameras. NTSB's recommendation to FTA (R-17-13) is as follows: "Require the installation, in all controlling locomotive cabs and cab car operating compartments, of crash- and fire-protected inward- and outward-facing audio and image recorders capable of providing recordings to verify train crew actions and train operating conditions. The devices should have a minimum 12-hour continuous recording capability with recordings that are easily accessible for review, with appropriate limitations on public release, for the investigation of accidents and as a tool to improve operational safety." FTA directed CUTR to conduct the research necessary to assist APTA in the development of a recommended practice for the industry for the installation of inward- and outward-facing camera and audio recorders, consistent with R-17-13.</p>					
15. SUBJECT TERMS Transit safety, audio and video surveillance, SMS processes, transit event investigations					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES 31	19a. NAME OF RESPONSIBLE PERSON
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER

TABLE OF CONTENTS

1	Executive Summary
4	Section 1: Project Background, Context, and Scope
7	Section 2: Literature Review
13	Section 3: Survey of Rail Transit Equipment
19	Section 4: Key Findings
21	Appendix A: Transit Agency Data Collection Form

LIST OF FIGURES

14	Figure 3-1:	Vehicles With and Without Inward-Facing Cameras
14	Figure 3-2:	Vehicles With and Without Outward-Facing Cameras
14	Figure 3-3:	Heavy Rail Vehicles With and Without Inward-Facing Cameras
15	Figure 3-4:	Light Rail Vehicles With and Without Inward-Facing Cameras
15	Figure 3-5:	Streetcars With and Without Inward-Facing Cameras
15	Figure 3-6:	Heavy Rail Vehicles With and Without Outward-Facing Cameras
16	Figure 3-7:	Light Rail Vehicles With and Without Outward-Facing Cameras
16	Figure 3-8:	Streetcars With and Without Outward-Facing Cameras
17	Figure 3-9:	Agencies With and Without Cameras Operating in Infrared
17	Figure 3-10:	Agencies With and Without Crash- and Fire-Protected Memory Modules
18	Figure 3-11:	Data Module Retention in Hours

LIST OF TABLES

8	Table 2-1:	Video/ Audio-Related Specifications for Rail Modes
9	Table 2-2:	Comparison of Technical Camera Specifications
9	Table 2-3:	EDR Crash Worthiness and Fire Standards
10	Table 2-4:	FRA 49 CFR Part 229, Appendix D – Crashworthiness Criteria Option A
10	Table 2-5:	FRA 49 CFR Part 229, Appendix D – Crashworthiness Criteria Option B
11	Table 2-6:	Comparison of Specification and Criteria Outlined in NTSB Recommendation
12	Table 2-7:	Summary of RFPs for Inward- and Outward-Facing Recording Devices

ABSTRACT

The National Transportation Safety Board (NTSB) has investigated numerous railroad and rail transit accidents for which inward- and outward-facing camera and audio recorders provided or could have provided an unequivocal record of a train operator's actions. Recognizing the importance of this technology, the Fixing America's Surface Transportation (FAST) Act of 2015 mandated that the Federal Railroad Administration (FRA) issue regulations requiring video recorders. The mandate also gave the Secretary of Transportation the discretion to require audio recordings on all FRA-regulated passenger (intercity and commuter) trains operating on the general railroad system. As a result of additional events and ongoing investigations, including the collision of two Southeastern Pennsylvania Transportation Authority (SEPTA) trains in Upper Darby, Pennsylvania, on February 21, 2017, the NTSB issued one safety recommendation to FTA and two to SEPTA associated with inward- and outward-facing cameras. NTSB's recommendation to FTA (R-17-13) is as follows: "Require the installation, in all controlling locomotive cabs and cab car operating compartments, of crash- and fire-protected inward- and outward-facing audio and image recorders capable of providing recordings to verify train crew actions and train operating conditions. The devices should have a minimum 12-hour continuous recording capability with recordings that are easily accessible for review, with appropriate limitations on public release, for the investigation of accidents and as a tool to improve operational safety." FTA directed CUTR to conduct the research necessary to assist APTA in the development of a recommended practice for the industry for the installation of inward- and outward-facing camera and audio recorders, consistent with R-17-13.

This report is based on investigations and tests conducted by Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads, with the direct participation of the Federal Transit Administration (FTA) and the Center for Urban Transportation Research (CUTR) at the University of South Florida. The contents of this report imply no endorsements whatsoever by TTCI of products, services, or procedures, nor are they intended to suggest the applicability of the test results under circumstances other than those described in this report. TTCI makes no representations or warranties, either express or implied, with respect to this report or its contents. TTCI assumes no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential, or any other kind of damages resulting from the use or application of this report or its contents.

Background

The Federal Transit Administration (FTA) entered into a Cooperative Agreement with the University of South Florida (USF) and its Center for Transit Research (CUTR) to develop a Safety Standards Research Plan to identify areas of transit safety risk in the industry and inventory existing transit safety standards or those in other transportation industries that could be modified to address transit safety-related risks and establish focus areas for further research. This was done to support FTA's Safety Policy Program and efforts of the public transportation industry's Standard Development Organization (SDO), the American Public Transportation Association (APTA).

To effectively meet the research needs for this project, the CUTR research team, including subject matter experts from CUTR and the Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), conducted background research on safety critical emphasis areas that may be used to support the identification and modification or development of voluntary standards or recommended practices through APTA's Standards Program.

Context

The National Transportation Safety Board (NTSB) has investigated numerous railroad and rail transit accidents for which inward- and outward-facing camera and audio recorders provided, or could have provided, an unequivocal record of a train operator's actions. These recorders can greatly improve operational safety, accident investigations, and management oversight, particularly in accidents in which the train operator is killed or suffers memory loss. Recognizing the importance of this technology, the Fixing America's Surface Transportation (FAST) Act of 2015 mandated that the Federal Railroad Administration (FRA) issue regulations requiring video recorders. The mandate also gave the Secretary of Transportation the discretion to require audio recordings on all FRA-regulated passenger (intercity and commuter) trains operating on the general railroad system. FRA has not promulgated regulations associated with this Congressional action, although it is proposing rulemaking for cameras in passenger locomotives and cab cars.¹

As a result of additional events and ongoing investigations, including the collision of two Southeastern Pennsylvania Transportation Authority (SEPTA) trains in Upper Darby, Pennsylvania, on February 21, 2017, the NTSB issued one safety recommendation to FTA and two to SEPTA associated with inward- and outward-facing cameras. NTSB's recommendation to FTA (R-17-13) is as follows:

¹<https://www.federalregister.gov/documents/2019/07/24/2019-14407/locomotive-image-and-audio-recording-devices-for-passenger-trains>.

Require the installation, in all controlling locomotive cabs and cab car operating compartments, of crash- and fire-protected inward- and outward-facing audio and image recorders capable of providing recordings to verify train crew actions and train operating conditions. The devices should have a minimum 12-hour continuous recording capability with recordings that are easily accessible for review, with appropriate limitations on public release, for the investigation of accidents and as a tool to improve operational safety.

FTA directed CUTR to conduct the research necessary to assist APTA in the development of a recommended practice for the industry for the installation of inward- and outward-facing camera and audio recorders, consistent with R-17-13.

An independent CUTR Transit Standards Working Group was formed comprising industry stakeholders from small and large U.S. transit agencies and representatives of APTA, the Community Transportation Association of America (CTAA), the National Rural Transit Assistance Program (RTAP), and the Amalgamated Transit Union (ATU). The role of the Working Group is to inform the project team, validate and verify the need for given standards, make recommendations related to transit safety-related standards, and provide overall advice and direction to the project team.

Methods

The research team conducted a literature review of available standards related to inward- and outward-facing camera and audio recording devices and their use on all rail modes. An evaluation of the standards was completed by comparing the criteria to the NTSB recommendation. In addition, the research team developed a survey instrument disseminated by APTA to U.S. rail transit agencies to determine the degree to which inward- and outward-facing cameras and recording devices are being used. Findings from the literature review and survey results were discussed with CUTR's Transit Standards Working Group for their input and feedback.

Key Findings

- **Literature Review** – Results of the gap analysis of available standards meeting the NTSB recommendation indicated that:
 - All standards for cameras are missing a component of the major categories identified in NTSB R-17-13, specifically crash and fire protection and minimum recording time.
 - No rail-specific standards are provided for audio recordings.
- **Survey Results** – Survey data collected indicated that implementation of inward- and outward-facing cameras is significant in transit rail, with light rail

installations of almost 100%. However, very few agencies with inward- and outward-facing cameras have data modules that are crash- or fire-protected.

The Transit Standards Working Group identified the following three key findings:

- **Finding 1: Industry standardization of inward- and outward-facing camera and audio devices can aid future agency procurements.** Standards may include the following details:
 - Location of video cameras (inside and outside controlling cabs)
 - Audio/microphone recording to verify train crew actions
 - Minimum recording data retention time (onboard and agency requirements) necessary for the transit environment
 - Data output format standardization
 - Crash- and fire-protected memory module requirements
 - Data upload guidelines for real-time viewing and data downloads

In addition, voluntary standards organizations may consider developing guidelines on data upload for real-time viewing (wireless) instead of having to rely solely on manual downloads.
- **Finding 2: Implementation of these devices and incorporation of expanded and corresponding technology applications can provide additional data and benefits to transit agencies.** These applications and their benefits may include but are not limited to:
 - Inward-facing cameras with machine learning agents and image algorithms that can monitor operator performance, detecting fatigue and awareness
 - Outward-facing cameras that can be used to monitor wayside assets to detect obstructions and defects
 - Outward-facing cameras with image algorithms currently used in the freight rail industry that examine ties and track-related infrastructure
- **Finding 3: Research indicates that several existing industry standards already incorporate both technical and performance standards and/or specifications related to inward- and outward-facing cameras, including:**
 - Operation of inward- and outward-facing cameras
 - Required maintenance
 - Practices to effectively use recordings for accident/incident investigations
 - Overall safety improvement initiatives

Project Background, Context, and Scope

Background

The Federal Transit Administration (FTA) entered into a Cooperative Agreement with the University of South Florida and its Center for Transit Research (CUTR) to develop a Safety Standards Research Plan to identify areas of transit safety risk within the industry, inventory existing transit safety standards or those in other transportation industries that could be modified to address transit safety-related risks, and establish focus areas for further research to support FTA's Safety Policy Program and the efforts of the public transportation industry's Standard Development Organization (SDO), the American Public Transportation Association (APTA).

To effectively meet the research needs for this project, the CUTR research team included subject matter experts from CUTR and Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), which are conducting background research on safety-critical emphasis areas that may be used to support the identification and modification or development of voluntary standards or recommended practices through APTA's Standards Program.

Context

The National Transportation Safety Board (NTSB) has investigated numerous railroad and rail transit accidents where inward- and outward-facing camera and audio recorders provided, or could have provided, an unequivocal record of a train operator's actions. These types of recorders can greatly improve operational safety, accident investigations, and management oversight, particularly in accidents in which the train operator is killed or suffers memory loss. The Fixing America's Surface Transportation (FAST) Act of 2015 mandated that the Federal Railroad Administration (FRA) issue regulations requiring video recorders and gave the Secretary of Transportation the discretion to require audio recordings on all FRA-regulated passenger trains operating on the general U.S. railroad system. FRA has not yet promulgated regulations associated with this Congressional action.

As a result of additional events and ongoing investigations, including the collision of two Southeastern Pennsylvania Transportation Authority (SEPTA) trains in Upper Darby, Pennsylvania, on February 21, 2017, the NTSB issued

one safety recommendation to FTA and two to SEPTA associated with inward- and outward-facing cameras. NTSB's recommendation to FTA (R-17-13) is as follows:

Require the installation, in all controlling locomotive cabs and cab car operating compartments, of crash- and fire-protected inward- and outward-facing audio and image recorders capable of providing recordings to verify train crew actions and train operating conditions. The devices should have a minimum 12-hour continuous recording capability with recordings that are easily accessible for review, with appropriate limitations on public release, for the investigation of accidents and as a tool to improve operational safety.

FTA directed the CUTR research team to conduct the research necessary to assist APTA in the development of a recommended practice for the industry for the installation of inward- and outward-facing camera and audio recorders, consistent with R-17-13.

An independent CUTR Transit Standards Working Group was formed comprising industry stakeholders from small and large U.S. transit agencies, APTA, the Community Transportation Association of America (CTAA), the National Rural Transit Assistance Program (RTAP), and the Amalgamated Transit Union (ATU). The role of the Working Group is to inform the project team, validate and verify the need for given standards, make recommendations related to transit safety-related standards, and provide overall advice and direction to the project team.

Scope

The methodology for this project included background research that incorporated a literature review and analysis of the current standards or specifications being used in the industry and in other countries for the procurement, installation, operation, interoperability, and maintenance of hardware/software and associated data of inward- and outward-facing camera and audio recording devices. Specific activities included the following:

- Literature search on current standards used in industry (transit rail and non-rail modes, commuter rail, and freight rail) and in other countries.
- Review of standards or guidelines issued for crash and fire protection of audio and video recording devices and cameras from national and international SDOs.
- Survey of U.S. rail transit and commuter rail agencies.
- Review of industry-issued Requests for Proposals (RFPs) or other competitive procurement documents specifically designed for the procurement of inward- and outward-facing cameras and recording devices. This review was

conducted to determine the use of existing standards and to identify any locally-defined standards or system specifications included in procurement documents that could be used to inform the research team.

The findings and results of this research were provided to the Transit Standards Working Group for their input and feedback. During a two-day meeting in July 2018, the use of inward- and outward-facing cameras and audio recording devices was discussed. Following are several main points of the discussion:

- Some transit agencies that have installed both video and audio recording devices have not activated the audio portion as a result of discussions with labor unions related to privacy protections for employees.
- An industry standard would be helpful to develop procurement technical specifications.
- Real-time data viewing via cellular service or Wi-Fi would improve data access across operating system platforms and devices and allow transit personnel in the field to access information quickly and easily.

Literature Review

A literature search was conducted to identify available specifications for inward- and outward-facing video and audio devices currently being used in the rail industry. The data sources used to identify the varying specifications included FRA, APTA, AAR, the Institute of Electrical and Electronic Engineers (IEEE), the Rail Safety and Standards Board (RSSB), and the International Electrotechnical Commission (IEC). From these sources, specifications were identified that address camera selection and location, digital recording systems, digital high-speed networks, closed caption television (CCTV) systems, fitment guidance, rail transit vehicle passenger emergency systems, camera operating criteria such as resolution and frames per second, and crashworthiness of modules. The identified standards were reviewed and categorized as follows:

- Regulation or industry standards defined by FRA or by the *AAR Manual of Standards and Recommended Practices*.
- Voluntary standards published by other entities, including but not limited to AAR, APTA, RSSB, IEC, and IEEE.

Each specification was categorized as either a regulation or a voluntary standard by type of specification, defined as follows:

- Video – specifications that outline capturing video data inside or outside the cab.
- Audio – Specifications that outline capturing audio data inside or outside the cab.
- Memory Module – Specifications that outline capabilities of memory modules in terms of being crash- and fire-protected; the memory module is the data storage device for all video and audio recorders or devices.

Video/Audio-Related Specifications

Specifications that outline details related to inward- and outward-facing cameras and/ or audio were identified and are shown in Table 2-1, summarized as follows:

- **APTA-IT-CCTV-RP-001-II** – A broad standard for selection of cameras for transit applications, including inward- and outward-facing cameras in the cab of rolling stock and outside the rail car as well as station platforms and other secure areas at which video may want to be taken; other secure areas could include stations and transit office buildings. Includes details on how to select cameras for optimal image quality and provides guidance on resolution, frame rate, lighting, and more that are applicable to inward- and outward-facing cameras and allow for some flexibility of selection of cameras based on needs of the agency. Does not include details on audio recordings.

- **RSSB GM/GN 2606** – Specific to inward- and outward-facing camera installation on rolling stock, provides details on camera specifications, including resolution, frame count, and position, and specifically calls out other industry standards for the memory module crash and fire requirements (specifically IEEE 1482.1²). Does not include details on audio recordings.
- **FRA Safety Advisory 2016-03** – Safety advisory with a recommendation for installation of inward- and outward-facing camera and audio recording devices for controlling locomotive cabs of trains traveling over 30 mph that are regulated by FRA. Does not contain specifics of camera and audio technical specifications but details that video and audio recordings should be able to verify train crew actions.
- **APTA RT-VIM-S-026-12** – Covers several elements of passenger emergency systems for new rail transit vehicles and outlines requirements and guidelines for each system. Includes section on system performance standards for outward forward- and side-facing cameras and microphones. Limited on video and audio system technical requirements.

Table 2-1

Video/Audio-Related Specifications for Rail Modes of Transportation

Country	Transportation Mode	Document	Title
US	Transit Rail	APTA IT-CCTV-RP-001-11	Selection of Cameras, Digital Recording Systems, Digital High-Speed Networks, and Train Lines for Use in Transit-Related CCTV Systems
Great Britain	All Rail	RSSB GM/GN 2606	Guidance on the Fitment of Forward- and Rear-Facing Cameras to Rolling Stock
US	Freight/Commuter Rail	FRA Safety Advisory 2016-03	Guidance on the Fitment of Forward- and Rear-Facing Cameras to Rolling Stock
US	Transit Rail	APTA RT-VIM-S-026-12	Rail Transit Vehicle Passenger Emergency Systems

Two specifications were found that include minimum technical specifications for cameras, as shown in Table 2-2, with differences between the specifications identified for each operating criterion. As technologies change rapidly and Great Britain's RSSB GM/GN 2606 specification was published after APTA IT-CCTV-RP-001-11, some criteria may require high resolution and higher frame rates. This suggests that it might be better to list performance standards instead of technical specifications for camera selection due to rapidly-changing technology.

²Institute of Electrical and Electronics Engineers, 2013, IEEE Std 1482.1, IEEE Standard for Rail Transit Vehicle Event Recorders, New York, NY.

Table 2-2*Comparison of Technical Camera Specifications*

Operating Criteria	APTA IT-CCTV-RP-001-11	RSSB GM/GN 2606
Resolution	704V x 480H resolution (4CIF)	HD resolution (1920 x 1080)
F-stop	Electronic iris control or automatic gain	Electronic iris control or automatic gain
Frames per sec (fps)	5 fps – low motion area; 15 fps – frequent motion; 30 fps – moving vehicles	Minimum 12 fps, with 20–25 fps for speeds of 100 mph or more
Color/black & white	Recommends color when possible	Color–day, B&W–night
Additional functional requirements	None	Ability to distinguish colors of railway signals (in daylight)

Crash and Fire Protection of Memory Module Specifications

Standards related to crash and fire protection of memory modules also were identified. These standards define the environmental conditions in which the data storage device must be able to survive. Specifications that detail the criteria are summarized in Table 2-3; note that all are directly aimed at Event Data Recorder (EDR) data storage systems but are applicable to data storage for video and audio recordings.

Table 2-3*EDR Crash Worthiness and Fire Standards*

Document	Title	Testing Requirement
FRA 49 CFR Appendix D Part 229	Criteria for specific crashworthiness tests that need to be completed	Criteria for Certification of Crashworthy Event Recorder Memory Module
AAR Manual of Standards (MSRP) Standard S-5512	Event Recorders for Locomotives	Refers to IEEE 1482.1 requirements
IEEE Standard 1482.1	Standard for Rail Transit Vehicle Event Recorder	Criteria for periodic inspection/test and crashworthiness but does not define how to test; crashworthiness criteria define types of tests; supplier responsible for showing it meets criteria.
IEC 62625-1	Electronic Railway Equipment – On-Board Driving Data Recording System	Criteria for specific crashworthiness tests that need to be completed.

These standards specify the testing requirements for the data storage device or EDR to survive a crash and/or fire. Requirements in all documents focus on survivability of the EDR data storage device during a crash that would cause it to receive a major impact, be penetrated or crushed, catch fire, or be submerged in various liquids such as fuel, oil, or salt water. The IEC 62625-1 specification details the same testing outlined in the other two documents with two different

options. Although directed at EDR data storage, the requirements could be applied to data storage devices for video and audio recordings. Tables 2-4 and 2-5 show the testing requirements.

Table 2-4

FRA 49 CFR Part 229, Appendix D – Crashworthiness Criteria Option A (same as IEEE 1482.1 Criteria)

Parameter	Value	Duration	Remarks
Fire, High Temperature	750 °C (1400 °F)	60 min	Heat source – oven
Fire, Low Temperature	260 °C (500 °F)	10 hrs	N/A
Impact Shock	55 g	100 ms	1/2 sine crash pulse
Static Crush	110kN (25,000 lbf)	5 min	N/A
Fluid Immersion	#1 diesel, #2 diesel, water, saltwater, lube oil	Any single fluid, 48 hrs	N/A
	Firefighting fluid	10 min, following immersion above	Immersion followed by 48 hours in dry location without further disturbance
Hydrostatic Pressure	Depth equivalent = 15 m (50 ft)	48 hrs at nominal temperature of 25 °C (77 °F)	N/A

Table 2-5

FRA 49 CFR Part 229, Appendix D – Crashworthiness Criteria Option B

Parameter	Value	Duration	Remarks
Fire, High Temperature	1000 °C (1832 °F)	60 min	Heat source – open flame
Fire, Low Temperature	260 °C (500 °F)	10 hrs	Heat source – oven
Impact Shock—Option 1	23 g	250 ms	N/A
Impact Shock—Option 2	55 g	100 ms	1/2 sine crash pulse
Static Crush	111.2kN (25,000 lbf); 44.5kN (10,000 lbf)	5 min (single “squeeze”)	Applied to 25% of surface of largest face
Fluid Immersion	#1 diesel, #2 diesel, water, saltwater, lube oil, firefighting fluid	48 hrs each	N/A
Hydrostatic Pressure	46.62 psig (= 30.5 m or 100 ft)	48 hrs at nominal temperature of 25 °C (77 °F)	N/A

Standards

A review of available standards identified key differences. The research team compared these standards to NTSB R-17-13, establishing the degree to which each addresses specific criteria for inward- and outward-facing camera and recording devices. Areas of comparison were the following:

- Location criteria for all controlling locomotive cabs and cab-car operating compartments
- Video and audio capability to verify train crew actions and train operating conditions
- Crash and fire protection of memory module
- Continuous recording time capability
- Ease of accessibility for review, with appropriate limitations for public release, investigation of accidents, and use of data to improve operational safety

Table 2-6 lists the standards identified and whether a given standard details the criteria needed to address the NTSB recommendations. Overall, no specification or standard is available to the transit industry that meets all criteria outlined in the NTSB recommendation; specifically, no specifications incorporate audio and video recordings and requirements for crash and fire protection.

Table 2-6

Comparison of Specification and Criteria Outlined in NTSB Recommendation

Specification	Location Criteria	Audio/Video Recording Devices to Verify Actions	Crash- and Fire-Protected	Minimum 12-hr Continuous Recording	Criteria on Review of Data
APTA IT-CCTV-RP-001-11	2	3 (audio) 1 (video)	3	2	1
APTA RT-VIM-S-026-12	1 (outward) 3 (inward)	1 (outward)	2	2	3
RSSB GM/GN 2606	1	3 (audio) 1 (video)	1	1	1
49CFR Part 229	3	3	1	1	3
IEEE 1482.1	3	3	1	1	3
IEC 62625-1	3	3	1	1	3

“1” = if specification includes details to meet criteria outlined by NTSB; “2” = specification provides guidance but requires interpretation to meet NTSB recommendation; “3” = specification does not include details to meet NTSB recommendation.

Request for Proposals (RFPs)

A review was conducted of RFPs or other competitive procurement documents specifically designed for the procurement of inward- and outward-facing cameras and recording devices released by the rail industry. This assisted in determining the use of existing standards and identifying locally-defined standards or system specifications that could be used to inform the research team. RFPs for the following were reviewed:

- Connecticut DOT
- Metra

- SEPTA – Silverliner V, Silverliner IV, Bombardier coaches, locomotives, work fleets
- Metrolink
- Amtrak
- Metro North and Long Island Railroad (MTA)

The review is summarized in Table 2-7. Specifically requested in the RFPs were both inward- and outward-facing crew compartment cameras and a microphone for audio recording, and several specified the actual manufacturer or model to be used. All but one required crash- and fire-protected data devices; only four specified FRA 49 CFR Part 229 criteria.

Table 2-7

Summary of RFPs for Inward- and Outward-Facing Recording Devices

RFP	Inward	Outward	Microphone	Manufacturer/Model	Crash-Protected
Connecticut DOT	•	•	•	Wabtec LDRS-V	Memory module, FRA Standard
Metra	•	•	•	Not specified	Memory module, FRA 49 CFR Part 229
SETPA Silverliner V	•	•	•	MobileView PENTA L	Fire-, impact-, water-resistant
SEPTA Silverliner IV	•	•	•	DTI MDR5L or MobileView PENTA L	Fire-, impact-, water-resistant
SEPTA Bombardier cars, locomotives, work fleets	•	•	•	DTI MDR5L	Fire-, impact-, water-resistant
Metrolink	•	•	•	Railhead LDVRH4	Not specified
Amtrak	•	•	•	Not specified	Compliant with FRA 49 CFR Part 229
MTA	•	•	•	Not specified	Compliant with FRA 49 CFR Part 229

Details on the specific technical requirements in the RFPs for cameras and microphones were also reviewed and are summarized as follows:

- Number of cameras installed is dependent on operation and number of cab locations (cabs at both ends of married pair, for example).
- Resolution and frame rates were not always specified, but several RFPs used APTA IT-CCTV-RP-001-II guidance at a minimum.
- Other details have varied requirements, such as standard- to wide-angle lens, color and infrared camera.

Survey of Rail Transit Equipment

In June and July 2018, APTA surveyed transit agencies on their use of inward- and outward-facing camera devices in their vehicles. The purpose of the data collection effort was to:

- Measure the use of inward- and outward-facing recording devices in the industry.
- Identify specifications transit agencies have used or will be using in rail vehicle procurements that include installation of inward- and outward-facing cameras and audio recording devices.³
- Identify specifications transit agencies have used or will be using for installation of inward- and outward-facing recording devices for mid-life vehicle rehabilitations.

A copy of the data collection form is provided in Appendix A. In total, 25 agencies provided partial or complete survey data.

Survey Results

The data collected found that of 5,450 transit vehicles in service, approximately 68% have inward- and outward-facing cameras installed (Figures 3-1 and 3-2). For light rail vehicles, 100% were equipped with outward-facing cameras and 83% with inward-facing cameras. For heavy rail vehicles, 55% were equipped with outward-facing cameras and 61% with inward-facing cameras. For street cars, 98% were equipped with outward-facing cameras and 93% with inward-facing cameras. Figures 3-3 through 3-8 display the breakdown of equipment installed with inward- and outward-facing cameras by transit rail mode.

³Distinction between inward-facing cameras monitoring crew actions and inward-facing cameras in general was not done for this study. Discrimination between outward and outward forward-facing cameras was also not done for this study. Future research could include an effort to further quantify the rail transit camera data based on location and camera sight lines.

Figure 3-1

Vehicles With and Without Inward-Facing Cameras

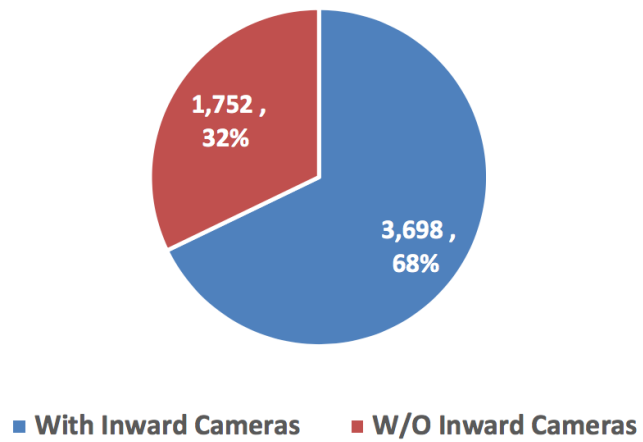


Figure 3-2

Vehicles With and Without Outward-Facing Cameras

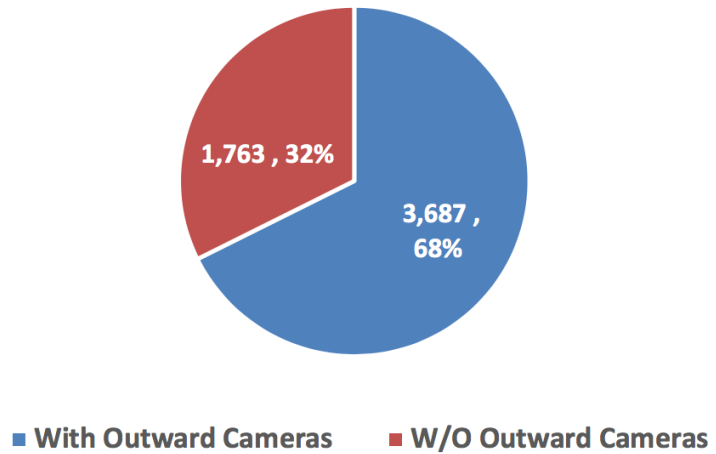


Figure 3-3

Heavy Rail Vehicles With and Without Inward-Facing Cameras

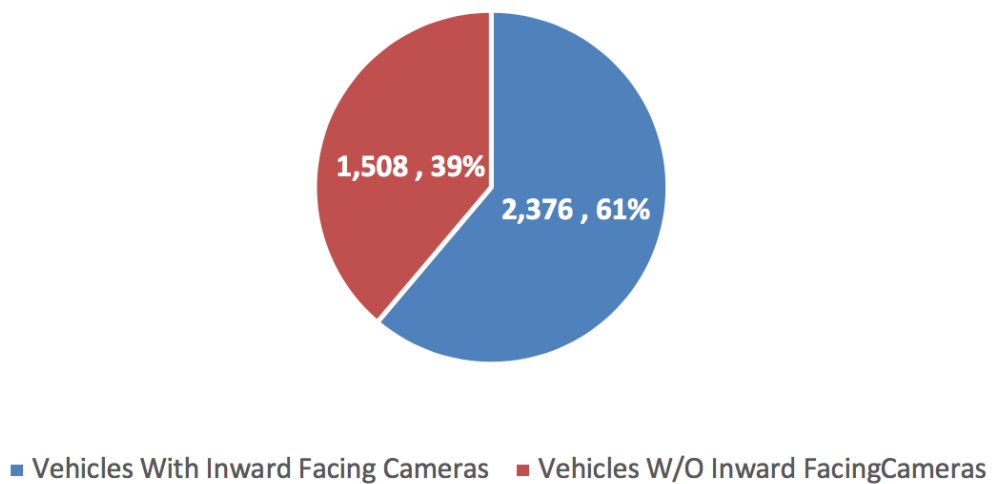
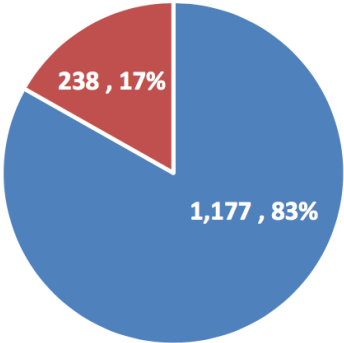


Figure 3-4

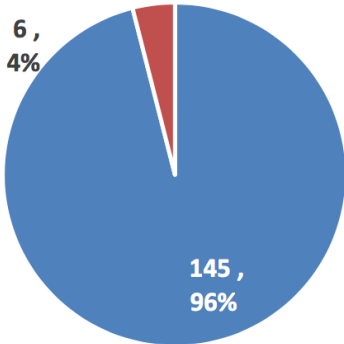
Light Rail Vehicles With and Without Inward-Facing Cameras



■ Vehicles With Inward Facing Cameras ■ Vehicles W/O Inward FacingCameras

Figure 3-5

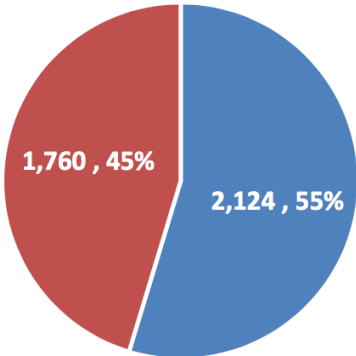
Streetcars With and Without Inward-Facing Cameras



■ Vehicles With Inward Facing Cameras ■ Vehicles W/O Inward FacingCameras

Figure 3-6

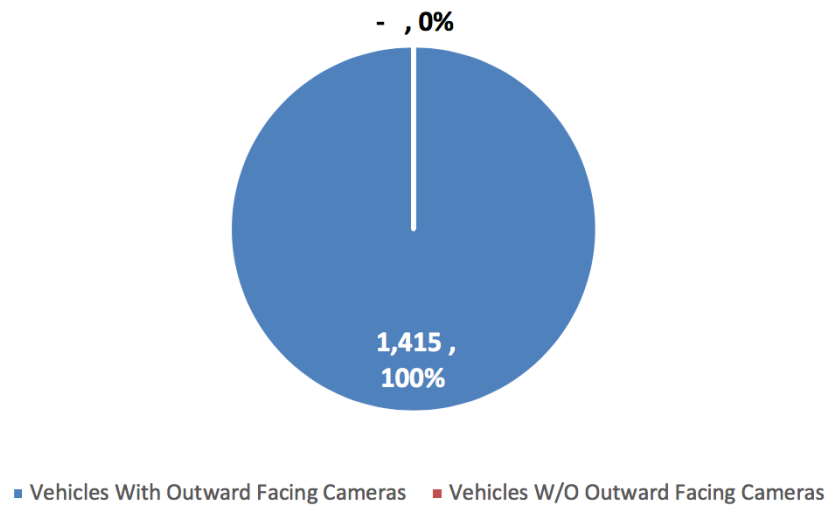
Heavy Rail Vehicles With and Without Outward-Facing Cameras



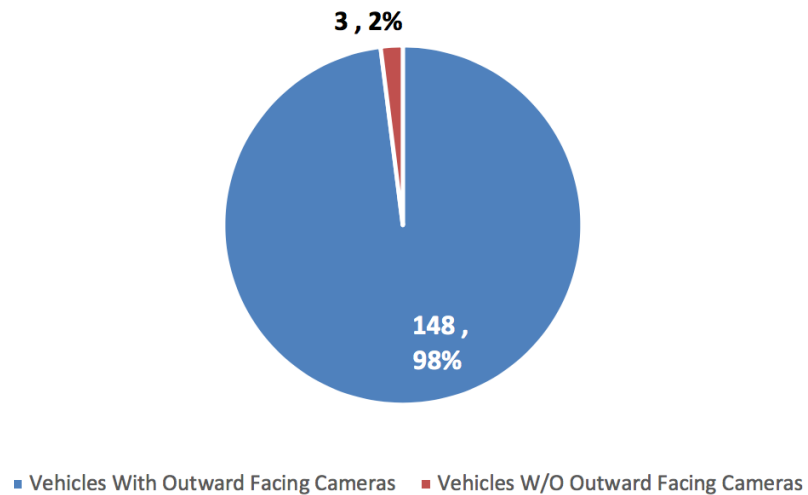
■ Vehicles With Outward Facing Cameras ■ Vehicles W/O Outward Facing Cameras

Figure 3-7

*Light Rail Vehicles
With and Without
Outward-Facing
Cameras*

**Figure 3-8**

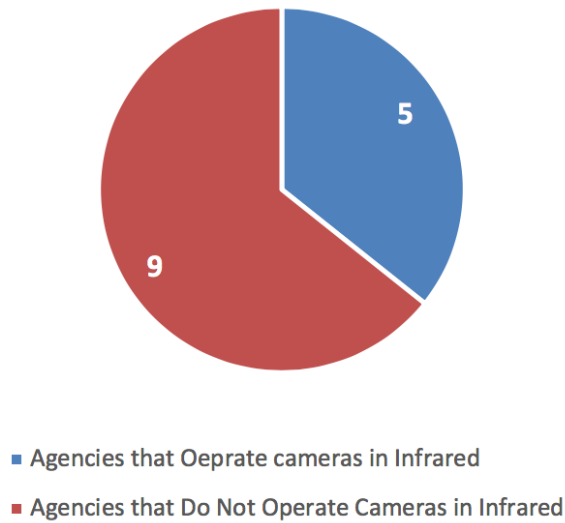
*Streetcars With and
Without Outward-
Facing Cameras*



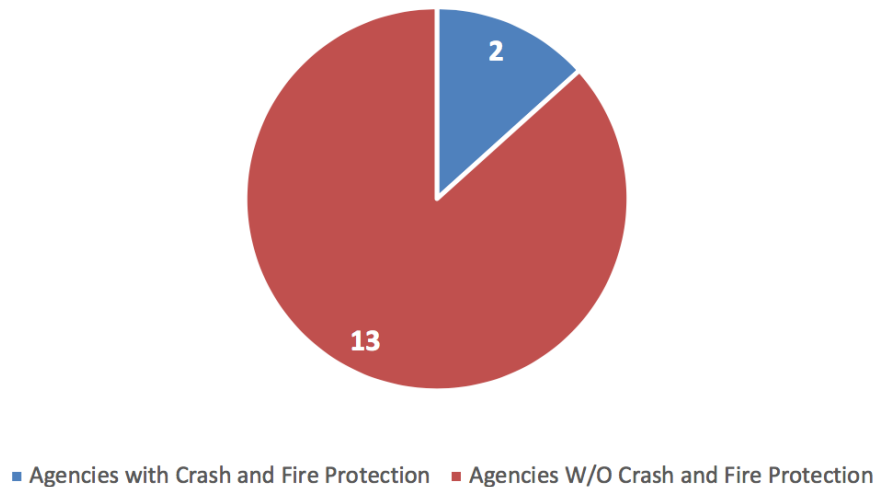
The survey also requested information on inward- and outward-facing camera specifications from agencies—in particular, if cameras operated in the infrared spectrum, information on the maximum recording times and if the data module was crash- and fire-protected. Only 14 agencies responded to the question, with 5 responding that their cameras operate in the infrared spectrum (Figure 3-9). Of the agencies that responded that inward- and outward-facing cameras were installed on rail vehicles, only two indicated that data storage was crash- and fire-protected (Figure 3-10).

Figure 3-9

Agencies With and Without Cameras Operating in Infrared

**Figure 3-10**

Agencies With and Without Crash- and Fire-Protected Memory Modules



The survey asked agencies how long the memory module maintained recorded data (Figure 3-11). Data hold times are dependent on density of the video, which varies due to lighting and passenger loads. NTSB recommendation R-17-13 specifies a 12-hour minimum retention time, but 12 hours may not meet agency requirements for near-miss event reconstructions because of the nature of responding to near-miss events after being reported. Minimum hold times should be calculated per APTA IT-CCTV-RP-001-11, Selection of Cameras, Digital Recording Systems, Digital High-Speed Networks and Trainlines for Use in Transit-Related CCTV Systems. (Note: Researchers verified that Cleveland hold times in the figure below are correct for newer railcars; its legacy cars hold an average of 180 hours of data.)

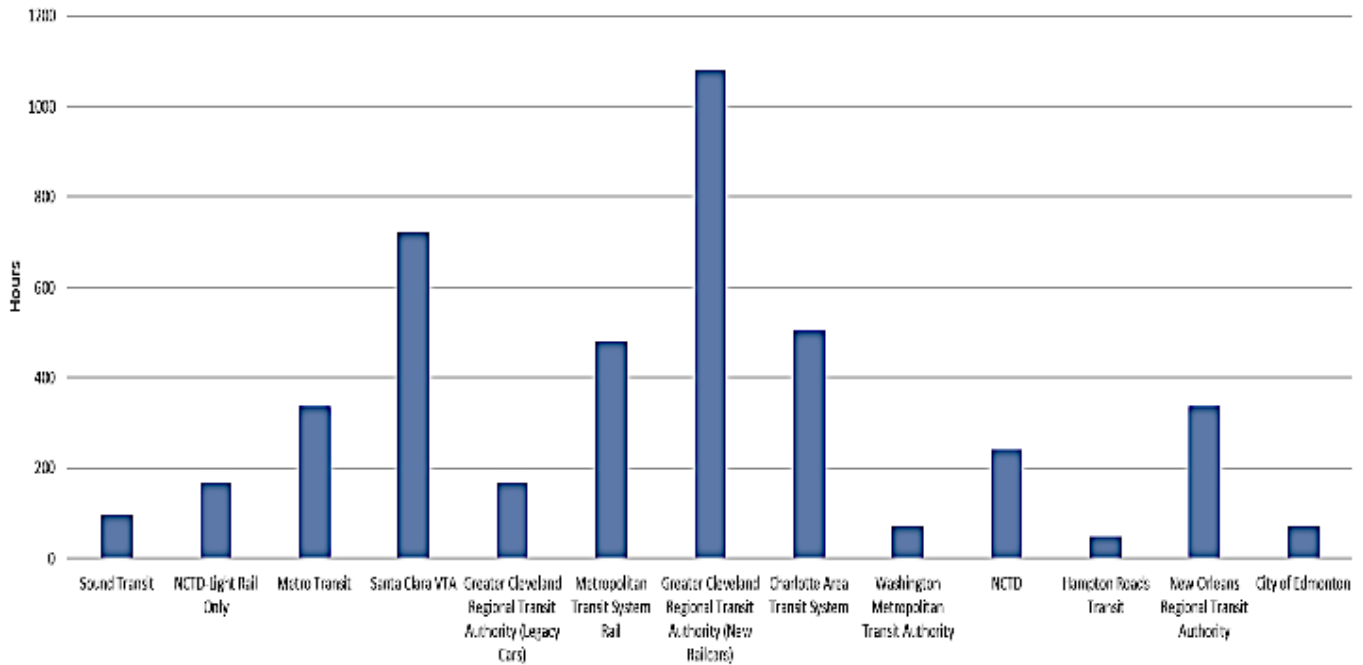


Figure 3-11

Agency Data Module Retention in Hours

The survey asked agencies questions related to how recordings are used by their agency if inward- and outward-facing cameras are used. The NTSB recommendation suggests use for both incident investigation and operational safety improvements. Agencies that provided a response indicated they use recordings primarily for incident or accident investigation, but some indicated that recordings are used for backup for litigation purposes by customers, operational rule compliance, and troubleshooting maintenance issues. Recordings from inward- and outward-facing cameras could benefit transit agencies in many ways via the ability to conduct research related to human factor risks, hours of service, and biometrics for future standards development initiatives.

Key Findings

A review of available standards related to inward- and outward-facing camera and audio devices and their use on all rail modes was completed. Evaluation of the standards compared standards criteria to NTSB recommendation R-17-13, and the identified standards and subsequent evaluation were compared with specific aspects of NTSB R-17-13 as a gap analysis to determine if any current standards or specifications appropriately address the recommendation. Results of the gap analysis of standards available that meet NTSB R-17-13 indicate the following:

- All standards for cameras are missing a component of the major categories identified in NTSB R-17-13, specifically, crash and fire protection and minimum recording time.
- No technical or performance standards are provided for audio recordings.
- Minimal defined performance is provided for technical and reliability specifications for interior-mounted crew compartment-mounted cameras. Development of technical and performance specifications is recommended for transit vehicles.
- Once standardization of transit vehicle video and audio systems is achieved, development of recommended practices and standards for operation, maintenance, and use for incident/accident investigations and operational safety improvement initiatives will be necessary.

A survey of inward- and outward-facing camera implementation by U.S. transit agencies was completed through a data collection form disseminated by APTA to measure the use of inward- and outward-facing cameras in the industry and to identify specifications that are or will be used in rail vehicle procurements. Collected data were analyzed by TTCI and indicated that implementation of inward- and outward-facing cameras is significant in transit rail, with 100% of light rail installations. However, very few agencies with inward- and outward-facing cameras have data modules that are crash- or fire-protected.

Based on the review of research results and discussions with the CUTR Transit Standards Working Group, the following three key findings were identified:

- **Finding 1: Industry standardization of inward- and outward-facing camera and audio devices can aid future agency procurements.** Standards may include the following details:
 - Location of video cameras (inside and outside controlling cabs)
 - Audio/microphone recording to verify train crew actions

- Minimum recording data retention time (onboard and agency requirements) necessary for transit environment
- Data output format standardization
- Crash- and fire-protected memory module requirements
- Data upload guidelines for real-time viewing and data downloads
- **Finding 2: Implementation of these devices and incorporation of expanded and corresponding technology applications can provide additional data and benefits to transit agencies.** These applications and their benefits may include but are not limited to:
 - Inward-facing cameras with machine learning agents and image algorithms that can monitor operator performance, detecting fatigue and awareness
 - Outward-facing cameras that can be used to monitor wayside assets to detect obstructions and defects
 - Outward-facing cameras with image algorithms currently used in the freight rail industry that examine ties and track-related infrastructure
- **Finding 3: Research indicates that several existing industry standards already incorporate both technical and performance standards and/or specifications related to inward- and outward-facing cameras, including:**
 - Operation of inward- and outward-facing cameras
 - Required maintenance
 - Practices to effectively use recordings for accident/incident investigations
 - Overall safety improvement initiatives

A

Transit Agency Data Collection Form

Purpose: Transportation Technology Center, Inc. (TTCI) and the Center for Urban Transportation Research (CUTR) at the University of South Florida were tasked by the Federal Transit Administration (FTA) with researching and developing and/or modifying voluntary standards for inward- and outward-facing video camera and recording systems. These cameras record actions of operators as well as events that occur outside and in front of the rail vehicle.

As part of this effort, CUTR and TTCI are collecting data from the industry on the use of inward- and outward-facing cameras in the transit industry today. Please reply to the following questions by July 11, 2018. Your timely response is appreciated.

1. Agency Name: _____
 Name/Position of Employee: _____
 Employee Email: _____ Employee Phone Number: _____
2. Does your agency operate the following rail mode (s)?
 Heavy Rail _____ Light Rail _____ Streetcar _____
3. What is your fleet size by mode? Heavy Rail _____ Light Rail _____
 Streetcar _____
4. Do you have rail vehicles equipped with outward-facing cameras? Yes _____
 No _____
5. How many rail vehicles are equipped with outward-facing cameras by mode:
 Heavy Rail _____ Light Rail _____ Streetcar _____
6. Do you have rail vehicles equipped with inward-facing cameras? Yes _____
 No _____
7. How many rail vehicles are equipped with inward-facing cameras that have a view of the train operator by mode? Heavy Rail _____ Light Rail _____
 Streetcar _____
8. Who and what are the manufacturers and models of the inward- and/or outward-facing cameras and recording systems? _____
9. What is the frame rate and resolution of your inward and/or outward facing cameras? _____
10. During the day, do your inward- and/or outward-facing cameras operate in color or in black & white? _____

11. During night, do your inward- and outward-facing cameras operate in color or in black & white? _____
12. What is the maximum continuous recording time that can be stored by your camera's memory system? _____
13. How often do you upload camera recording data in the back office? _____
14. Do your camera systems record audio? Yes _____ No _____
15. Do your camera systems operate in infrared? Yes _____ No _____
- a. If you answered "Yes" to #15, under what conditions do your cameras operate in infrared? _____
16. Is your data storage system for camera system crash- and fire-protected? Yes _____ No _____
- a. If you answered "Yes" to #16, what crash and fire proof specification(s) does your data storage system meet, or please list the crash and fireproof specifications of your systems (or provide the details in an email). _____
17. Is your data storage system remote (wireless upload)? Yes _____ No _____
18. If you answered "No" to questions #4 and/or #6, have you considered implementing inward/outward-facing cameras on your rail vehicles? Yes _____ No _____
19. If you answered "Yes" to question #17, what specifications/ requirements were considered for the cameras in terms of resolution, frame rate, etc., and transferring data wirelessly? _____
20. If your rail transit agency has inward/outward-facing cameras or if you answered "Yes" to questions #4 and/or #6, how do you currently use the data or plan to use the data, and how do you avoid misuse? _____
21. If you answered "No" to question #18, please cite your top two reasons for not considering implementation of inward/outward-facing cameras on your rail vehicles. _____
22. If you answered "Yes" to question #4 and/or #6, on average, how many times do you use the data for investigation or other uses in a year? _____



U.S. Department of Transportation
Federal Transit Administration

U.S. Department of Transportation
Federal Transit Administration
East Building
1200 New Jersey Avenue, SE
Washington, DC 20590
<https://www.transit.dot.gov/about/research-innovation>