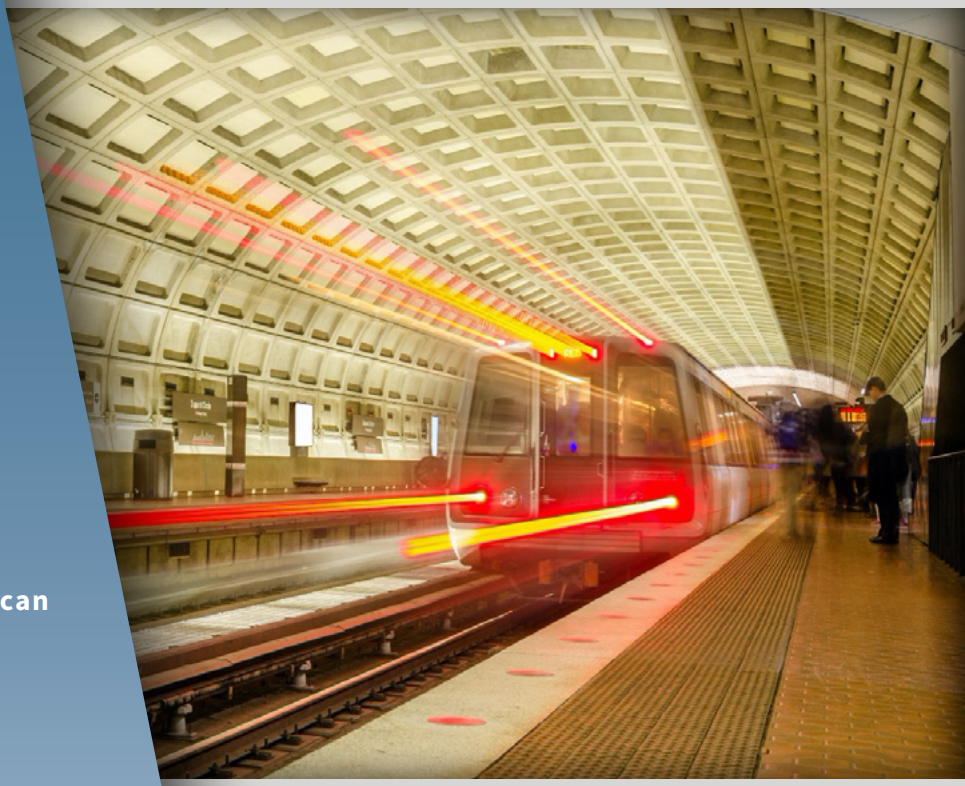
FTA Report No. 0226

FTA RESEARCH
FEDERAL TRANSIT ADMINISTRATION

Use of Event Data Recorders in Rail Transit



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U.S. Department of Transportation
Federal Transit Administration

AUGUST
2022

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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	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	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)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC

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14. ABSTRACT

Event Data Recorders (EDRs) are devices installed on rail vehicles to record specific data such as speed, braking commands, automatic train control information, and operator commands. This project focused on data collected from computers and sensors on board a rail vehicle; video-based EDRs were not considered in this work. The objective of the study was to gather information on current EDR standards and use and to evaluate rail transit industry needs for EDR standards and guidance. Findings of this report and subsequent guidance on standards for EDRs in rail transit can be leveraged to guide public transit agency decision-making. Some findings include the need for a common data format to view EDR data easily by agencies and NTSB investigators and for a written specification explicitly related to rail transit EDR data retention, as states currently have different data retention policies.

15. SUBJECT TERMS
Event data recorder, EDR, rail data recorder, accident investigation tool

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Abstract

Event Data Recorders (EDRs) are devices installed on rail vehicles to record specific data such as speed, braking commands, automatic train control information, and operator commands. This project focused on data collected from computers and sensors on board a rail vehicle; video-based EDRs were not considered in this work. The objective of the study was to gather information on current EDR standards and use and to evaluate rail transit industry needs for EDR standards and guidance. Findings of this report and subsequent guidance on standards for EDRs in rail transit can be leveraged to guide public transit agency decision-making. Some findings include the need for a common data format to view EDR data easily by agencies and NTSB investigators and for a written specification explicitly related to rail transit EDR data retention, as states currently have different data retention policies.

This report was prepared for the Center for Urban Transportation Research (CUTR) by Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), Pueblo, Colorado. It is based on investigations and tests conducted by TTCI with the direct participation of CUTR to criteria approved by them. 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. The results and findings contained in this report are the sole property of CUTR. They may not be released by anyone to any party other than CUTR without the written permission of CUTR. TTCI is not a source of information with respect to these tests, nor is it a source of copies of 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.

Executive Summary

The Federal Transit Administration (FTA) entered into a Cooperative Agreement with the Center for Urban Transportation Research (CUTR) at the University of South Florida to research areas of transit safety risk, identify existing standards and recommended practices to address those areas of risk, and perform a gap analysis to establish the need for additional standards, guidance, or recommended practices to support and further the safe operation of the nation's public transportation industry. At the direction of FTA, CUTR and its research partner, the Transportation Technology Center, Inc. (TTCI), are performing research and background studies on various topics to collect the information necessary for FTA to provide findings to the industry on voluntary standards or publish guidance documents or resource reports to assist the industry in mitigating areas of safety risk. The findings of this report and subsequent guidance can be leveraged to guide public transit agency decision-making.

One area of research is Event Data Recorders (EDRs), devices installed on rail vehicles to record specific data such as speed, braking commands, automatic train control information, and operator commands. The EDR research for this project focused on data collected from computers and sensors on board a rail vehicle; video-based EDRs were not considered in this work.

A review of available reports, standards, and regulations related to EDRs and their use on all rail modes was completed. Documents were reviewed for applicability to light rail, streetcar, and heavy rail modes. Evaluation of the industry need for EDR standards was completed by reviewing National Transportation Safety Board (NTSB) and research reports and through feedback received from CUTR's Transit Safety Standards Working Group established for industry stakeholder input. Identified industry needs are summarized in the following focus areas:

- Installation of EDRs with specific minimum criteria for accident investigation data collection
- Standard(s) that include the following criteria:
  - Data to collect (minimum)
  - Sample rates/filtering requirements
  - Health monitoring of EDR
  - Survivability/crashworthiness of EDR
  - Output
- Installation of EDRs on older vehicles going through a mid-life rehabilitation due to legacy equipment.
- EDRs for data collection during events such as accidents and for maintenance and operational information as needed by the agency.

- EDRs with an option to export data to a universal format that can be easily read without special software.

Available standards were compared against industry needs to evaluate their effectiveness to address needs and if any modifications must occur to make them applicable to rail transit. The results of the gap and modification analysis indicate the following:

- All specifications except for the Association of American Railroads (AAR) *Manual of Standards and Recommended Practices* (MSRP) Standard S-5512 and the Institute of Electrical and Electronics Engineers (IEEE) 1482.1 standard are missing a component of the major categories identified as the industry need. AAR MSRP S-5512 standard references the IEEE 1482.1 standard.[1,2]
- IEEE 1482.1 specifications target all major categories identified for data collection and EDR design for incident-based data collection.
- A universal data output format from EDRs is not described in any specification; any specification implemented would need to be modified to address the universal output.
- Modifications would be required for all specifications related to operational/maintenance EDRs.

Collecting data about EDR use in transit agencies in the U.S. was completed through a survey delivered to all State Safety Oversight (SSO) managers. Data collected indicated that although EDR use in transit vehicles has increased since the last survey was completed in 2007, EDRs are installed in only about 40% of the transit vehicles of agencies that participated in the data collection effort. Of the transit agencies surveyed, 67% of their light rail vehicles, 35% of their heavy rail vehicles, and 14% of their streetcars were equipped with EDRs.

Based on the research results and feedback from the Transit Safety Standards Working Group EDR Subcommittee, several findings were developed:

Finding 1: IEEE 1482.1 provides EDR standard criteria[3] that may be used for new or rehabilitated rail transit vehicles.

- IEEE 1482.1 is an industry-accepted standard, as many agencies are using it in Requests for Proposals (RFPs) and technical specifications for new vehicles. In addition, the standard addresses all major categories identified during the industry needs research.

[1] Institute of Electrical and Electronics Engineers (IEEE), 2013, IEEE Std 1482.1, IEEE Standard for Rail Transit Vehicle Event Recorders, New York, NY.
[2] Association of American Railroads (AAR), adopted 2004, *AAR Manual of Standards and Recommended Practices*, Section M, Standard S-5512, Locomotive Event Recorder Download Standard.
[3] IEEE, *op. cit.*

- Approximately 60% of vehicles operated in service by the transit agencies surveyed for this study are not equipped with EDRs. EDR installation during a mid-life rehabilitation due to legacy equipment could be cost-prohibitive for the remainder of the life of the vehicle.

Finding 2: Research identified the need for a common data download format to view EDR data easily, which would be useful for both agencies and NTSB investigators. Information collected from agencies indicated multiple types of special software for viewing the data depending on the type and manufacturer of the EDR.

Finding 3: Public transit agencies may choose to define local operational/maintenance EDR data collection requirements based on their needs, including how the data are used and how long the data are retained after download.

Finding 4: EDR specifications do not list any requirements for data security related to download via WI-FI-enabled EDRs.

Finding 5: There is no written specification explicitly related to rail transit EDR data retention. Furthermore, states currently have different data retention policies due to varied state requirements. Public transit agencies may consider establishing specifications on the length of time an agency should retain data from an EDR after download for accident/incident investigation.

Section 1

Introduction

The Federal Transit Administration (FTA) entered into a Cooperative Agreement with the Center for Urban Transportation Research (CUTR) at the University of South Florida to research areas of transit safety risk, identify existing standards and recommended practices to address those areas of risk, and perform gap analyses to establish the need for additional standards, guidance, or recommended practices to support and further the safe operation of the nation's public transportation industry. At the direction of FTA, CUTR and its research partner, the Transportation Technology Center, Inc. (TTCI), are performing research and background studies on various topics to collect the information necessary for FTA to provide findings to the industry on voluntary standards or publish guidance documents or resource reports to assist the industry in mitigating areas of safety risk.

The findings of this report and subsequent guidance can be leveraged to guide public transit agency decision-making. One area of research is Event Data Recorders (EDRs), devices installed on rail vehicles to record specific data such as speed, braking commands, automatic train control information, and operator commands. EDRs are typically used in crash/event investigation and maintenance and diagnostics. Other transportation industries, most notably the aviation industry, use EDRs extensively.

Background

Since the mid-1990s, FTA has financed, supported, and participated in developing safety and technical standards and recommended practices for the public transportation industry. It has supported the transit safety standard program coordinated through the industry's official Standards Development Organization (SDO), the American Public Transportation Association (APTA). FTA also has partnered closely with other Department of Transportation (DOT) Modal Administrations, including the Federal Highway Administration (FHWA), the Federal Railroad Administration (FRA), the National Highway Traffic Safety Administration (NHTSA), and the Federal Motor Carrier Safety Administration (FMSCA) on multimodal regulations and rulemakings to adopt standards that affect, or have the potential to affect, public transportation.

In 2012, the Moving Ahead for Progress in the 21st Century Act (MAP-21) amended Federal transit law by authorizing a new public transportation safety program at 49 U.S.C. § 5329 to provide FTA with a new mandate for public transportation safety authority. Section 5329(b)(2)(c) directed FTA to take into consideration "relevant recommendations of the National Transportation Safety Board (NTSB)" and "recommendations of and best practices standards developed by the public transportation industry." FTA's Safety Program was

further strengthened in the Fixing America's Surface Transportation (FAST) Act in 2015 and, most recently, in 2021 through the Bipartisan Infrastructure Law.

Project Scope

The EDR research focused on data collected from computers and sensors on board rail transit vehicles; video-based EDRs were not considered in this work. For this research, the term rail transit includes light rail, streetcars, and heavy rail transit systems.

The following specific tasks were identified, and this report details the results of these tasks:

- Conduct background research to collect information on existing specifications or voluntary standards (rail- or transit-related) that could apply to the rail industry and analyze needs and gaps that exist for new standards to be developed.
- Collect data from industry stakeholders on the use of EDRs in transit vehicles, including information on specifications being used by the industry for mid-life overhauls and new procurement of transit vehicles.
- Review existing standards and specifications and identify those deemed inadequate or those needing modification or enhancement to make them applicable to rail transit; provide findings on existing standards that could be applied directly without any modifications.

CUTR's Transit Safety Standards Working Group, consisting of industry stakeholders from small and large U.S. transit agencies, informed the project team, validated and verified the need for given standards, issued findings related to transit safety-related standards, and provided overall advice and direction to the project team.

Section 2

Industry Need

The research team evaluated the need for EDR standards through a literature review of reports published by FRA, FTA, NTSB, and other entities; the Transit Safety Standards Working Group assisted in validating and verifying the research results.

NTSB Recommendations

A literature search of accident investigation reports published by the NTSB was completed to identify specific recommendations related to EDRs as follows:

- Safety Recommendation R-10-022 – In June 2009, an inbound Washington Metropolitan Area Transit Authority (WMATA) train struck a stopped inbound train. The accident resulted in nine deaths due to the telescoping of one train car onto another. The striking 1000-series Metrorail railcars involved in the accident were not equipped with onboard event recorders; thus, NTSB investigators had to compile other sources of information, including but not limited to trailing car and train-to-wayside communications data to determine speed, braking performance, and position time history of the colliding train. As a result, the NTSB recommended that WMATA "develop and implement a program to monitor the performance of onboard event recorders and ensure they are functioning properly."[4]
- Safety Recommendation R-02-19 – In 2001, two rear-end collisions occurred at the Chicago Transit Authority (CTA) within a two-month period. The investigation found deficiencies in CTA's management approach to ensure rules compliance and the data logger's performance related to preserving time. As a result of the two accidents, the NTSB recommended that FTA "require that new or rehabilitated vehicles funded by Federal Transit Administration grants be equipped with event recorders meeting Institute of Electrical and Electronics Engineers Standard 1482.1 for rail transit vehicle event recorders."[5]
- Multiple NTSB recommendations were made to the FRA regarding event recorders with hardened crashworthiness, fire-protection standards, and maintenance criteria to confirm that event recorders are working.[6,7,8]

Other Published Reports

Several different modes of transportation use and/or mandate EDRs. In 1967, the aviation industry was the first to mandate EDRs, commonly called black boxes, in commercial aircraft for use in accident investigation.

[4] National Transportation Safety Board (NTSB), 2010 "Safety Recommendation R-10-022."
[5] NTSB, 2002, "Safety Recommendation R-02-019."
[6] NTSB, 1998, "Safety Recommendation R-98-030."
[7] NTSB, 1997, "Safety Recommendation R-97-053."
[8] NTSB, 1997, "Safety Recommendation R-97-056."

In 2006, the auto industry released its final ruling (49 Code of Federal Regulations (CFR) Part 563) with work sponsored by NHTSA recommending that newly-manufactured personal automobiles have an EDR installed.[9,10] The standard defined the required data to be collected, survivability standards, and the data collection window (time before and after a crash).

In 1998, FTA published a report recommending EDRs for use in rail rapid transit systems.[11] The FTA report also provided historical data that served to validate and support the need for EDR use in rail transit systems. In addition, three types of EDRs were defined:

- Basic Event Recorder – Records accident and incident data that can be used for analysis by transit management and government investigators; used primarily for accident/incident investigation.
- Enhanced Event Recorders – Records all basic event recorder data and performance functions that could be used by maintenance personnel and engineering/management to diagnosis and monitor system performance.
- Monitoring and Diagnostic Recorders – Provides all basic and enhanced event recorder data collection but allows the data to be used in real-time by the operator and for historical performance data; this type of EDR may record more data functions and store data for longer periods of time.
- Although there is currently no regulation or industry standard for the installation of EDRs on rail transit (light rail, streetcar, heavy rail), some transit agencies procuring new rail vehicles include requirements for EDRs in their procurement technical specifications.
- Some rail modes have regulations and/or mandatory standards in place; freight and commuter rail has regulations mandated by the FRA and other standards developed by the AAR that define EDR requirements.[12,13,14] Details on those regulations and standards are provided in subsequent sections of this report.

Industry Stakeholder Discussion on EDRs

During a two-day meeting with the Transit Safety Standards Working Group in February 2017 and subsequent meetings with its EDR subcommittee members, the use of EDRs and the need for associated industry standards were discussed.

[9] National Highway Traffic Safety Administration, 2011, 49 CFR Transportation, Chapter V Part 563, Event Data Recorders.
[10] Canis, Bill, and Randall Peterman, David, 2014, "Black Boxes in Passenger Vehicles: Policy Issues," Congressional Research Service Report R43651.
[11] Poritzky, Diegbert, et al., 1998, "Event Recorders for Rail Rapid Transit Systems," Federal Transit Administration, FTA-VA-26-7004-98-1.
[12] Federal Railroad Administration (FRA), 2017, 49CFR Transportation, Chapter II, Part 229, Subpart C, Safety Requirements; 49CFR 229.135, Event Recorders, §49CFR 229.135, Washington, DC.
[13] FRA, 2017, 49CFR Transportation, Appendix D to Part 220, Criteria for Certification of Crashworthy Event Recorder Memory Module; 49CFR Appendix D to Part 229, Washington, DC.
[14] AAR, *op. cit.*

Several main points of the discussion between the industry stakeholders on the Transit Safety Standards Working Group and the research team are summarized as follows:

- EDRs should be required when procuring new transit vehicles, and at a minimum, the EDR should provide enough data for accident investigation.
- An industry standard should be identified to reference during new-vehicle procurement that provides detail on the minimum data to collect.
- Equipping EDRs on older vehicles going through a mid-life rehabilitation due to legacy equipment may be too costly and/or not feasible. Standards should allow waivers for mid-life vehicle rehabilitations if the cost to install EDRs is prohibitive based on the life of the vehicle.
- EDR installations on existing fleets due to legacy equipment should allow for an exemption waiver for a particular agency/fleet of vehicles.
- EDRs should be used for data collection during events such as accidents and for maintenance and operational information for the agency. EDRs for operational-based information could be used daily, weekly, or monthly as defined by the transit agency.
- Collection of maintenance and operational information from EDRs could require different retention rates than incident-based EDR data. Maintenance/operational data may also require more frequent or remote access to the data.
  - Reviewing data requires a special reader. Standards should be developed to define a universal data format to access the data without a special reader. For example, data should be available in a .csv or .txt format.
  - Rail transit EDRs should include the following requirements and parameters:
    - Data to collect (minimum)
    - Sample rates/filtering requirements
    - Health monitoring of EDR
    - Survivability/crashworthiness of EDR

Section 3

EDR Specification Research

A literature search on available EDR specifications was completed to identify rail industry standards currently in use. The identified standards were reviewed and categorized as follows:

- Regulations defined by FRA or AAR MSRP Standard S-5512.
- Voluntary standards published by other specification agencies, such as APTA or IEEE.[15,16]

In addition to categorizing the specification by regulation/voluntary standard, the literature was categorized by the type of specification, defined as follows:

- Design – Specification defines how the EDR should be designed structurally, how data should be downloaded, data storage rates, and more.
- Data collection – Specification defines what data should be collected, how often the data should be collected, what the filter rates should be used, and more.

Appendix A contains a list of all the specifications identified during this research.

FRA Regulations

The FRA has two specific regulations that list the requirements for EDRs. The two regulations shown in Table 3-1 apply to freight and commuter locomotives with or without railcars. 49 CFR 229.135 defines where the EDR must be located in a train with multiple locomotives and the type of data required to be collected. This regulation has been classified as a data collection specification.

49 CFR Appendix D to Part 229 is classified as a design specification type because it defines what performance criteria the EDR must meet to be considered DOT crashworthy. Certification tests include fire at two temperatures (high and low), impact shock, static crush, fluid immersion, and hydrostatic pressure.

[15] American Public Transportation Association, 2003, APTA-RT-VIM-RP-015-03, Recommended Practice for On-Board Recording Equipment Periodic Inspection and Maintenance, Washington, DC.
[16] IEEE, *op. cit.*

Table 3-1 *EDR Regulations for Specific Rail Modes of Transportation*

Country	Transportation Mode	Document	Title	Applicability	Specification Type
U.S.	Freight/ commuter rail	FRA 49 CFR 229.135	Event Recorders	Any train operating >30mph	Data collection
U.S.	Freight/ commuter rail	FRA 49 CFR Part 229.25 and 229.27	Inspection and Test for Event Data Recorders	Any train operating >30mph	Design
U.S.	Freight/ commuter rail	FRA 49 CFR Appendix D to Part 229	Criteria for Certification of Crashworthy Event Recorder Memory Module	Any train operating >30mph	Design

Standards for EDRs

Table 3-2 shows standards for EDRs identified during the literature search that are not regulatory. AAR MSRP Standard S-5512 is a standard for locomotive event recorders and applies to freight locomotives that will be interchanging on railroads serving North America (Canada, Mexico, U.S.). MSRP Standard S-5512 references the IEEE 1482.1 standard (third standard in Table 3-2). The APTA recommended practice standard shown in Table 3-2 prescribes maintenance inspection practices of EDRs to ensure that system devices are working and is categorized as a data collection specification. The IEEE 1482.1 standard has several design and data collection specifications. Of all the regulations and standards reviewed, IEEE 1482.1 is the most comprehensive and defines the following:

- Data to be collected
- Filtering, sampling, and storage rates
- EDR health monitoring requirements (is EDR working, state of battery charge)
- Crashworthiness requirements
- Output requirements, including retention requirements

Table 3-2 *EDR Standards for Specific Rail Modes of Transportation*

Country	Transportation Mode	Document	Title	Applicability	Specification Type
U.S.	Freight rail	AAR MSRP Standard S-5512	Event Recorders for Locomotives	Locomotives	Design & data collection
U.S.	All rail modes	APTA-RT-VIM-RP-015-03	Recommended Practice for On-Board Recording Equipment Periodic Inspection and Maintenance	Any rail vehicle equipped with EDR	Data collection
U.S.	All rail modes	IEEE Standard 1482.1	Standard for Rail Transit Vehicle Event Recorder	Any locomotive	Design & data collection

Section 4

Comparison of IEEE 1482.1 Standard and CFR Regulation Criteria

Both the IEEE 1482.1 standard and the FRA 49 CFR 229.135 regulation have multiple categories that define criteria of EDRs, including type of data to collect, crashworthiness of the EDR, and data retention rates. A comparison of the two specifications found the following similarities:

- Data storage – Both IEEE 1482.1 and FRA 49 CFR 229.135 define the minimum amount of EDR data to store in memory as 48 hours of data.
- Data collected – Both specifications define the signals to be recorded. FRA 49 CFR 229.135 criteria are aimed at locomotives/DMUs/EMUs and not necessarily rail transit vehicles, whereas the IEEE 1482.1 standard lists additional signals to be collected for transit vehicles. However, the IEEE 1482.1 standard lists a correlation between the channels to collect per the IEEE specification and the 49 CFR 229.135 regulation
- Crashworthiness – IEEE 1482.1 uses the same criteria as Option A listed in 49 CFR 229.135.
- Health monitoring of the system – Both specifications define EDR health monitoring by using self-tests designed into the EDR. If self-tests indicate a failure, further testing and maintenance are completed.

The following differences exist between the specifications:

- Location of EDR – FRA 49 CFR 229.135 specified the location of the EDR to be in the lead locomotive or in a locomotive that can record the specific information as it was in the lead locomotive; IEEE 1482.1 specifies one functioning EDR per transit car.
- Age of EDR installed, and type of locomotive/DMU/EMU – FRA 49 CFR 229.135 defines different criteria for equipment put in service based on the year installed.
- Preservation of data after download – FRA 49 CFR 229.135 lists the minimum time as one year to preserve data after download; IEEE 1482.1 does not provide any criteria related to the EDR data after it is downloaded.
- Documentation related to working EDRs – FRA 49 CFR 229.135 defines the documentation that is required to be filled out in relation to working EDRs and those removed from service; IEEE 1482.1 does not require any such documentation.
- Data collection sampling and filtering rates – FRA 49 CFR does not define sampling or filtering rates for signal collection; IEEE 1482.1 does.

Section 5 Retention of EDR Data after Download

A review of the available specifications identified differences among standards—in particular, data retention length after EDR data are downloaded. FRA 49 CFR 229.135 requires the downloaded data to be preserved for a minimum of one year after an accident/incident; the IEEE 1482.1 standard does not list any criteria for data retention after download. State and federal policies list data retention requirements, but they do not specifically address EDR data. Although not related to EDRs or data retention, two federal government documents list record retention policies in general. Table 5-1 shows the specifications and details regarding record retention.

Table 5-1 *Record Retention Standards (Non-EDR Specific)*

Country	Document	Summary
U.S.	FTA Best Practices Procurement Manual (BPPM)	Record retention for FTA grantees requires grantees to retain project-related documents for three years following completion of FTA-funded projects. If any litigation claim, negotiation, audit, or other action started before three-year period, records must be retained until completion of action and resolution or until end of three-year period, whichever is later.
U.S.	DOT Rule 49 CFR Part 40 Section 40.333	Drug and alcohol recordkeeping requires retention for five years from incident with positive drug test, alcohol concentration of 0.02 or greater, refusal to take test, and all follow-up tests.

Discussions with the Transit Safety Standards Working Group related to non-EDR specific data or record retention standards resulted in several discussion points of note:

- Agencies download EDR data for incident/accident investigations and operational/ maintenance-related data analysis. Any standards developed that list requirements for keeping data after download should specify the reason for download (i.e., accident/incident vs. routine maintenance analysis of railcars), and operational/maintenance data retention should be different from incident/accident data downloads.
- Specific federal EDR data retention length requirements could conflict with state data retention rates.
- Agencies will retain data after an incident/accident typically until any litigation, arbitration, or statute of limitation has passed.

Section 6 Gap Analysis

The research team conducted a comparison of the needs of the industry to the available recommendations, standards, and regulations. The main objectives of the gap analysis were as follows:

- Compare industry needs for the type of event targeted (incident vs. operational/maintenance) for data collection to the type of specifications published.
- Evaluate the specifications published for type of guidance for the following specification types. Note that the specification types are categorized as data collection or design, as referenced in Tables 3-1 and 3-2.
  - Minimum data requirements – categorized as Data Collection
  - Data collection methods (sampling rates, filtering, etc.) – categorized as Data Collection
  - Storage rates – categorized as Design
  - EDR system health monitoring – categorized as Design
  - Crashworthiness/testing – categorized as Design
  - Output – categorized as Design

Table 6-1 lists each specification and identifies with an "X" if the specification would target incident-based EDRs or if the specification could be used for operational/maintenance EDRs. In addition, the table lists the criteria categories and the specifications detail. Review of the specifications found that all specifications are applicable to an incident-type event. However, the only document that provides criteria for design and data collection explicitly for rail transit is the IEEE 1482.1 standard. Note the AAR MSRP Standard S-5512 also provides criteria for each specification by referencing the IEEE 1482.1 specification; the other specifications do not provide criteria related to all Data Collection or Design categories, as shown in Table 6-1.

In addition to reviewing the overall standard for criteria related to the major categories, the team evaluated the Format Output. Standardization of a universal non-proprietary format was one of the requests from the Working Group EDR Subcommittee. None of the specifications detail a requirement for a universal output format option.

The specifications for EDRs that could target operational/maintenance-related data collection may require some modifications, as they were not written specifically for operation/maintenance data collection. Each transit agency may use data from EDRs for operation/maintenance decisions differently. The criteria listed in the specifications that would require modification for operation/maintenance-related EDR data collection include the following:

- Download method – Agencies may want to use an alternative download method that is more conducive to collecting data regularly (daily or weekly, for example) without requiring a person to plug in a laptop or jump drive. This may be done by WI-FI or Ethernet connection, USB, or other universal cables. Specifications found for EDRs did not provide any criteria for alternative download methods or security related to WI-FI connection.
- Data channel sampling rates and filtering rates – Data channels that are not being used in incident investigation may not need to meet higher sampling rates.
- Storage rates – The storage rate of the additional operation/maintenance data channels could be different than the retention rates for incident data, depending on the frequency of download defined by the transit agency.

To summarize, the results of the gap analysis indicate the following:

- All specifications except for AAR MSRP Standard S-5512 and IEEE 1482.1 are missing components of the major categories identified as an industry need. The AAR MSRP Standard references the IEEE 1482.1 standard.
- IEEE 1482.1 targets all the major categories identified for data collection and EDR design for incident-based data collection.
- A universal output data format and the hardware required for EDR downloads are not described in any specifications.
- Modifications would be required for all specifications related to operational/maintenance EDRs.

Note: Evaluation of the standards in the gap analysis focused on the criteria related to data collection before an event of interest; analysis was not undertaken on what is done with the data after download, including data analysis requirements and duration of data retention. However, the research team recognizes that the IEEE 1482.1 standard does not address any criteria related to “after downloading of the data” and, in particular, retaining accident data after download.

Table 6-1 *Standard Comparison to Event Type and Specification Categorization*

Document	Title	Event Type Targeted		Specification Category					
		Incident	*Operational/ Maintenance*	*Minimum Data Requirements*	*Data Collection Method*	*Storage Rates*	*Health Monitoring of EDR*	*Crashworthiness*	*Output*
49 CFR 229.135	Event Recorders	Yes	Yes, but would require modifications	X		X			X
FRA 49 CFR Appendix B Part 229.25 and 229.27	Inspection and Test for Event Data Recorders	Yes	Yes, but would require modifications				X		
49 CFR Appendix D to Part 229	Criteria for Certification of Crashworthy Event Recorder Memory Module	Yes	Yes, but would require modifications					X	
AAR MSRP Standard S-5512 (note: references IEEE)	Event Recorders for Locomotives	Yes	Yes, but would require modifications	X	X	X	X	X	X
APTA-RT-VIM-RP-015-03	Recommended Practice for On-Board Recording Equipment Periodic Inspection and Maintenance	Yes	Yes, but would require modifications				X		
IEEE Standard 1482.1	Standard for Rail Transit Vehicle Event Recorder	Yes	Yes, but would require modifications	X	X	X	X	X	X

Section 7 Modifications to Specifications for Rail Transit Applicability

Existing EDR specifications were reviewed to identify modifications required to apply the standard to EDRs installed on rail transit vehicles (light, heavy, and streetcars). Table 7-1 presents the modifications to 49 CFR Part 229, AAR, and APTA standards that would be required to make each document and related sections applicable to rail transit. The modifications identified address only certain criteria for each specification area. For example, modifications required in the event 49 CFR Part 229 was revised for rail transit EDRs include expanded data collection. The specifications included in Part 229 were written for EDRs installed on locomotives and do not include the status of many systems, including but not limited to passenger doors, pantographs, propulsion current, or Automatic Train Control (ATC). Table 7-1 details additional modifications that would be required to apply these standards to rail transit vehicles. Future research may identify more transit specific signals that should be captured by EDRs.

Table 7-1 *Modifications to Specifications to Apply to Rail Transit Vehicles*

Document	Title	Type of Rail Vehicle Standard was Written	Modifications Required to Apply Standard to Transit Vehicles
FRA 49 CFR 229.135	Event Recorders (details data to collect only)	Train traveling >30 mph with locomotive equipped with EDR	Data to collect would need to be modified to include: • Multiple ATC status • Passenger door status • Pantograph or third rail status
FRA 49 CFR Appendix B Part 229.25 and 229.27	Inspection and Test for Event Data Recorders	Locomotive traveling > 30 mph	Would require modifications to language referring to FRA forms and requirements to report to FRA if data are requested
FRA 49 CFR Appendix D Part 229	Criteria for Certification of Crashworthy Event Recorder Memory Module	Locomotive traveling >30 mph	No changes required
AAR Manual of Standards (MSRP) Standard S-5512	Event Recorders for Locomotives	Locomotive	Refers to IEEE 1482.1 specification but changes would be required to refer to specification for rail transit vehicles data requirements and not locomotive only data required
APTA-RT-VIM-RP-015-03	Recommended Practice for On-Board Recording Equipment Periodic Inspection & Maintenance	Rail Transit Vehicles	No changes required
IEEE Standard 1482.1	Standard for Rail Transit Vehicle Event Recorder	Rail Transit Vehicles	Retention of data after download

Section 8 Specification Testing Requirements

The testing requirements included in the available specifications target only the health and crashworthiness of the EDR system (including battery). Inspection and checkouts of the EDR system are included in testing because it requires a collection of data on the health of the EDR system and is completed outside the normal use of the EDR. The specifications that detail the testing requirements are summarized in Table 8-1.

Table 8-1 *Testing Requirements*

Document	Title	Testing Requirement
FRA 49 CFR 229.135	Event Recorders	Identifies data to collect without additional information related to data downloads, crashworthiness, fire protection, or other factors.
FRA 49 CFR Appendix B Part 229.25 and 229.27	Inspection and Test for Event Data Recorders	Criteria for inspection of EDRs based on type of EDR installed. Lists specific intervals to check.
FRA 49 CFR Appendix D Part 229	Criteria for Certification of Crashworthy Event Recorder Memory Module	Criteria for crashworthiness and what tests need to be completed.
AAR MSRP Standard S-5512	Event Recorders for Locomotives	Refers to IEEE 1482.1 requirements.
APTA-RT-VIM-RP-015-03	Recommended Practice for On-Board Recording Equipment Periodic Inspection & Maintenance	Recommends periodic inspection and test time intervals for health of EDR system.
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. Leaves supplier responsible for showing it meets criteria.

Health testing of the EDR, including the unit's battery system, is specified in two different ways in standards. FRA 49 CFR 229 Appendix B and APTA-RT-VIM-RP-015-03 specify intervals required to check the functionality of the EDR. IEEE 1482.1 requires self-tests to report on the health status of the EDR.

In addition, the crashworthiness of EDRs is defined with specific criteria related to survivability. These criteria confirm that an EDR will be able to collect and maintain data during a crash. Two specifications define crashworthiness criteria—FRA 49 CFR Appendix D and IEEE 1482.1. FRA 49 CFR Appendix D has two options for crashworthiness, and an EDR supplier could choose either option. IEEE 1482.1 criteria match the criteria in Option 1 FRA 49 CFR 229 Appendix D.

Two specifications detail the crashworthiness requirements of EDRs—FRA 49 CFR Appendix D Part 229 and IEEE 1482.1. The requirements in both focus on the survivability of the EDR during a major impact crash, being penetrated or crushed, put in a fire, and submerged in liquid. Tables 8-2 and 8-3 show the testing requirements.

Table 8-2 *CFR 49 Crashworthiness Criteria – Option A (same as IEEE 1482.1)*

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	
Impact shock	55g	100 ms	1⁄2 sine crash pulse
Static crush	110kN (25,000 lbf)	5 min	
Fluid immersion	#1 diesel, #2 diesel, water, salt water, lube oil	Any single fluid, 48 hrs	
	Firefighting fluid	10 min, following immersion above	Immersion followed by 48 hrs in dry location without further disturbance
Hydrostatic pressure	Depth equivalent = 15 m. (50 ft)	48 hrs at nominal temperature of 25 °C (77 °F)	

Table 8-3 *FRA CFR 49 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	23gs	250 ms	
Impact shock—Option 2	55gs	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, salt water, lube oil, firefighting fluid	48 hrs each	
Hydrostatic pressure	46.62 psig (= 30.5 m or 100 ft)	48 hrs at nominal temperature of 25 °C (77 °F)	

Section 9

Data Collection of Rail Transit Equipment

From March to May 2017, State Safety Oversight (SSO) transit agencies were asked to provide information on EDR use in the respective transit agency vehicles. The purpose of the data collection effort was to:

- Update a study completed by FTA's Office of Safety and Security in 2007 to evaluate the change in EDR usage in rail transit vehicles.
- Identify any specifications transit agencies have used or will be using in rail vehicle procurements that include EDR installation.
- Identify any specifications transit agencies have used or will be using for EDR installation in mid-life rehabilitation of vehicles.
- Understand the primary use of EDRs at the agency.
- Determine the number of individuals who know how to interpret the data and if special software is required.

The 2007 study focused only on EDRs that meet the IEEE 1482.1 standard, whereas the 2017 study considered all standards. In addition, the 2007 study did not differentiate between light rail vehicles and streetcars, but the 2017 study separated the modes. A copy of the data collection form is provided in Appendix B.

In total, 42 agencies provided data in the 2017 study and 37 agencies provided data in the 2007 study. The agencies that responded and their equipment numbers from the 2007 and 2017 studies are provided in Appendix C.

Rail Transit Vehicles Equipped with EDRs

Data collected from the 2017 study showed that of 13,898 vehicles in service, only 40% have EDRs installed (Figure 9-1). Light rail vehicles were 67% of the vehicles equipped with EDRs, heavy rail vehicles accounted for 35%, and streetcars represented only 14%. Figure 9-2 displays the breakdown of equipment installed with EDRs by rail transit mode.

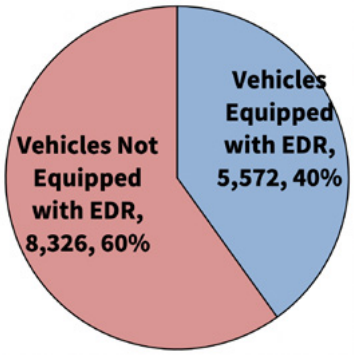

Figure 9-1 *Percent of vehicles with EDRs equipped vs. not equipped, 2017 study*

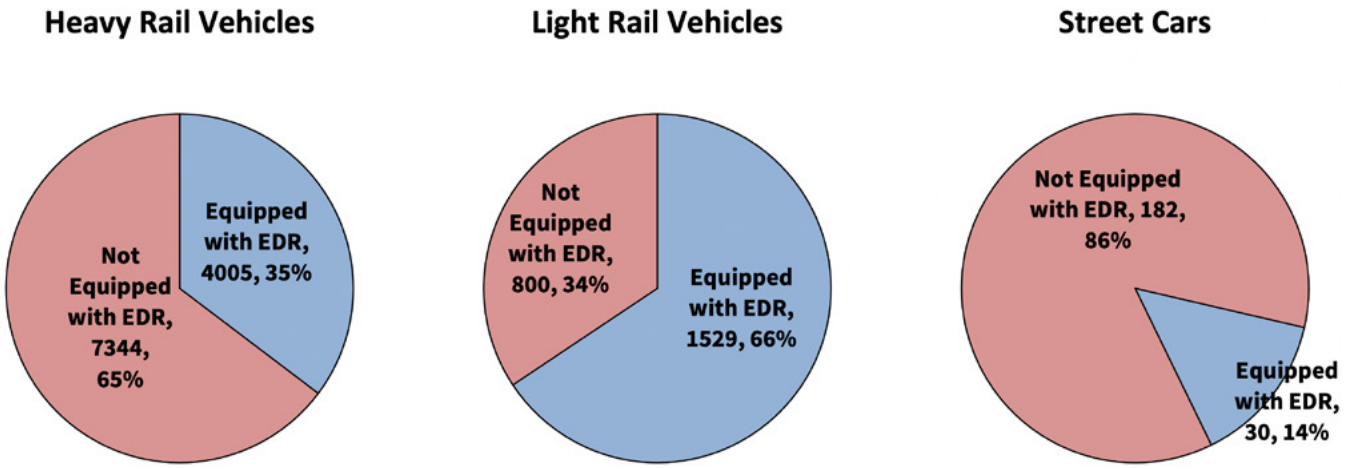

Figure 9-2 *Vehicles equipped with EDRs by rail transit mode*

Data collected in 2017 was compared to data collected in 2007 to understand industry changes related to EDR-equipped vehicles. Figure 9-3 shows the comparison of 2007 to 2017 data, indicating that the number of vehicles equipped with EDRs has increased. Although a number of agencies were represented in both surveys, others responded only to one or the other.

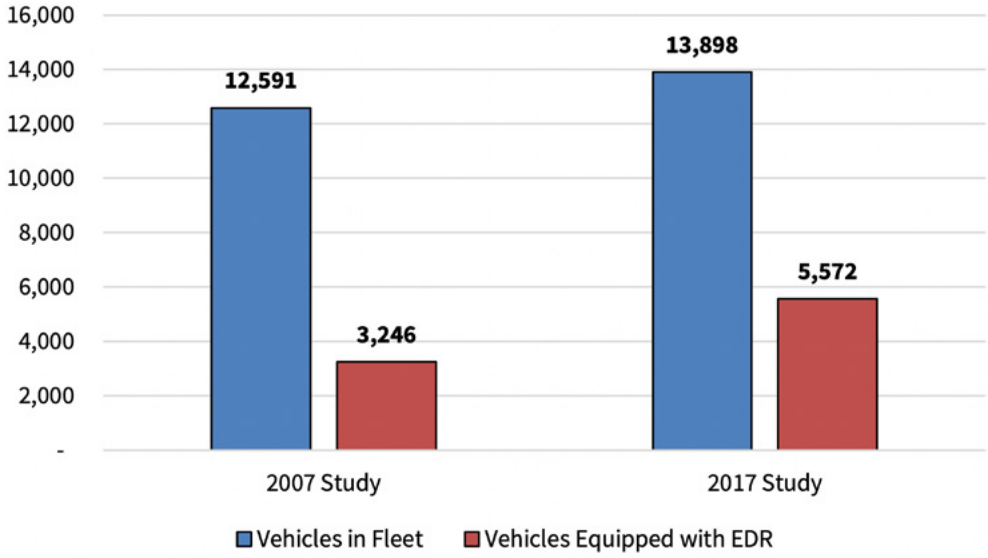

Figure 9-3 *Comparison of vehicles with EDR equipment, 2007 and 2017*

A comparison of the data by mode is shown in Figure 9-4. Note that the 2007 study did not differentiate between light rail and streetcar modes, whereas the 2017 study separated the modes; as a result, the streetcar mode shows zero data for 2007. Light rail vehicles equipped with EDRs have more than doubled

since the 2007 study, with 632 vehicles in 2007 compared to 1,529 vehicles in 2017. Heavy rail vehicles equipped with EDRs increased by approximately 600 vehicles.

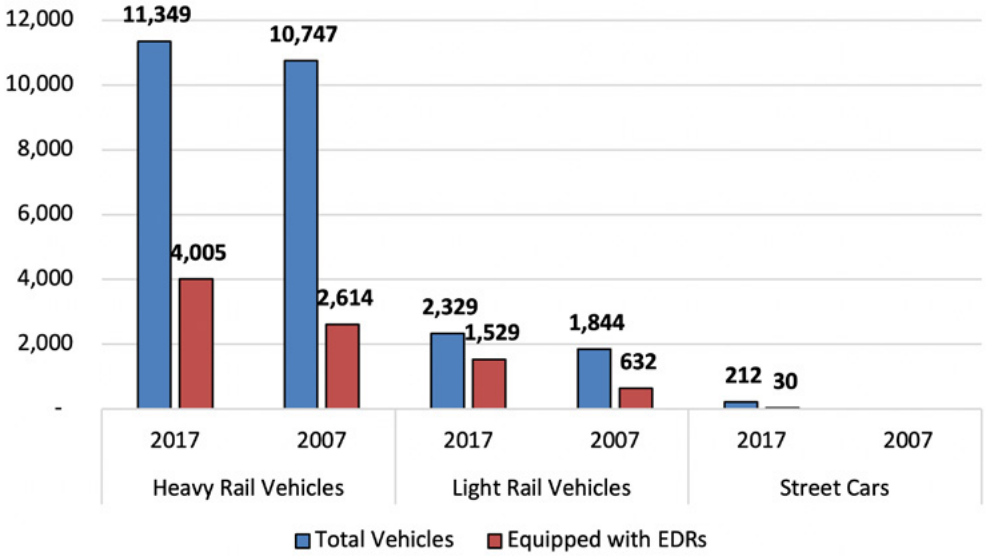

Figure 9-4 *Comparison of vehicles with EDR equipment by rail transit mode, 2007 and 2017*

EDR Specifications

The data collection effort also requested information from agencies on specifications for EDRs that were used in RFPs for new vehicles and/or specifications used on bids for the mid-life rehabilitation of vehicles. Although many of the agencies responding did not have immediate plans for mid-life rehabilitations or new vehicle procurements, and did not list a specification, agencies that were planning new vehicle procurements indicated that the IEEE 1482.1 standard was included as part of the RFP. Agencies that responded with IEEE 1482.1 or forwarded their procurement specification listing IEEE 1482.1 for EDRs include:

- Bay Area Rapid Transit (BART), Oakland, CA
- Honolulu Authority for Rapid Transit (HART) (Note: 80 vehicles not included in overall fleet counts because fleet not delivered)
- New York City Transit (NYCT) – Comparison of 2007 and 2017 responses indicated that the number of vehicles with EDRs decreased
- Chicago Transit Authority (CTA)
- Los Angeles County Metropolitan Transportation Authority (LACMTA)
- Massachusetts Bay Transportation Authority (MBTA), Boston

- Maryland Transit Administration (MTA-MD), Baltimore – EDR installation will be completed during mid-life overhaul of light rail vehicles (not completed as of 2017)
- Washington Metropolitan Area Transit Authority (WMATA), Washington, DC – 7000 car series

The agencies with responses indicating IEEE 1482.1 have either recently completed procurements or are in the procurement process. A comparison of their 2007 data to 2017 data indicates this information (Table 9-1).

Table 9-1 *Comparison of Fleet Data for Agencies Indicating IEEE 1482.1 Standard*

Agency	Rail Mode	2007		2017	
		Fleet Size	*Vehicles Equipped with EDRs*	*Fleet Size*	*Vehicles Equipped with EDRs or will be Equipped with EDRs*
BART	Heavy rail	669	0	669	669
HART (Honolulu)	Light rail	0	0	Will have 80	Will have 80
NYCT	Heavy rail	6,202	1,842	6,418	1,492
CTA	Heavy rail	1,190	0	1,459	714
LACMTA	Heavy rail	104	0	104	0
	Light rail	121	0	232	111
MBTA	Heavy rail	408	2	432	94
	Light rail	239	85	199	93
Maryland Transit Administration	Light rail	53	0	53	0
WMATA	Heavy rail	998	476	1,098	559

Three other agencies (Transdev/RTA New Orleans, Port Authority of Allegheny County, Port Authority Transit Corporation) indicated that they were considering EDR installation on mid-life vehicle overhauls but did not include a specification related to EDR criteria.

Agency Use of EDR Data

Questions were asked related to how EDR data are used by the agency. Based on discussions with EDR Subcommittee members before starting the data collection effort, it was suspected that incident investigation would be the primary purpose, and operation/maintenance-related data use may vary by agency. Of the agencies that responded on how EDR data is used from vehicles equipped with EDRs, 42 (agencies with multiple rail modes were counted as a single agency) indicated they used EDRs for incident or accident investigation. Of the 42 agencies, 31 used the EDR data for operation/maintenance-related decisions.

Software Required to View EDR Data

Agencies were also asked if special software was needed to view the EDR data. Of the agencies that responded, 39 indicated that special software was required to view the data. Although a question about the type of software required was not asked, a few agencies volunteered the names of the required software, including Quantum, WinDas, ADS4, and WAB-Link Interface Program.

Section 10 Conclusions and Findings

A review of available reports, standards, and regulations related to EDRs and their use on all rail modes was completed, and documents were reviewed for applicability to light rail, streetcar, and heavy rail modes. Evaluation of the industry needs for EDR standards was completed through reviews of NTSB and research reports and from feedback from the CUTR Transit Safety Standards Working Group. Industry needs identified are summarized in the following focus areas:

- Installation of EDRs in transit vehicles with specific minimum criteria for accident investigation data collection
- Guidelines for EDRs that include the following criteria:
  - Data to collect (minimum)
  - Sample rates/filtering requirements
  - Health monitoring of the EDR
  - Survivability/crashworthiness of the EDR
  - Output
- Cost and/or feasibility of equipping EDRs on older vehicles going through a mid-life rehabilitation or on legacy equipment; standards should allow waivers for mid-life vehicle rehabilitations if the cost to install EDRs is prohibitive based on the life of the vehicle.
- Consideration of EDRs for data collection during events such as accidents and for maintenance and operational information as needed by the agency.
- Option to export data to a universal format that can be easily read without special proprietary software.

The available standards were compared against the industry needs to evaluate the effectiveness of the standard to address those needs and if any modifications are needed to make them applicable to rail transit. The results of the gap and modification analysis indicate the following:

- All specifications except for AAR MSRP Standard S-5512 and IEEE 1482.1 are missing components of the major categories identified as industry needs. AAR MSRP Standard S-5512 references the IEEE 1482.1 standard.
- IEEE 1482.1 targets all major categories identified for data collection and EDR design for incident-based data collection.
- A universal output format from EDRs is not described in any standards/specifications; any specification implemented would require modifications to address universal output.
- Modifications would be required for all specifications related to operational/maintenance EDRs.

In 2017, the research team collected EDR information from transit agencies in the U.S. through SSO managers. This activity was performed to inform this research project and update information that was collected during a 2007 survey (used as a benchmark for this research project) performed by FTA through SSO managers. Data collected indicated that whereas EDR use in transit vehicles has increased since the first survey was completed in 2007, EDRs are installed in only about 40% of the transit vehicles of the agencies that participated in the data collection effort. Transit vehicles included in the study equipped with EDRs included 67% of light rail vehicles, 35% of heavy rail vehicles, and 14% of streetcars.

Several findings are developed based on the research results and feedback from the CUTR Transit Safety Standards Working Group EDR Subcommittee.

Finding 1: IEEE 1482.1 provides EDR standard criteria[17] that may be used for new or rehabilitated rail transit vehicles:

- IEEE 1482.1 is an industry-accepted standard, as many agencies use it in RFPs and technical specifications for new vehicles. In addition, the standard addresses all major categories identified during the industry needs research.
- Approximately 60% of the vehicles operated in service by the transit agencies surveyed were not equipped with EDRs. EDR installation during a mid-life rehabilitation due to legacy equipment could be cost-prohibitive for the remainder of the life of the vehicle.

Finding 2: Research identified the need for a common data download format to view EDR data easily, which would be useful for both agencies and NTSB investigators. Information collected from agencies indicated multiple types of special software for viewing the data depending on the type and manufacturer of the EDR.

Finding 3: Public transit agencies may choose to define local operational/maintenance EDR data collection requirements based on their needs, including how the data are used and how long they are retained after download.

Finding 4: EDR specifications do not list any requirements for data security related to download via WI-FI enabled EDRs.

Finding 5: There is no written specification explicitly related to rail transit EDR data retention. Furthermore, states currently have different data retention policies due to varied state requirements. Public transit agencies may consider establishing specifications on the length of time the agency will retain data from an EDR after download for accident/incident investigation.

[17] IEEE, *op. cit.*

Appendix A Rail EDR Standards and Specifications

Country	Type of Document	Document	Title	Applicability	Design/Data Collection	Event Type Targeted
U.S.	Regulation-freight/ commuter	FRA 49 CFR 229.135	Event Recorders	Locomotive traveling >30 mph	Design	Incident
U.S.	Regulation	FRA 49 CFR Appendix B Part 229.25 and 229.27	Inspection and Test for Event Data Recorders	Locomotive traveling >30 mph	Data collection	Incident
U.S.	Regulation-freight/ commuter	FRA 49 CFR Appendix D to Part 229	Criteria for Certification of Crashworthy Event Recorder Memory Module	Locomotive traveling >30 mph	Data collection	Incident
U.S.	Report-rail	FTA-VA-26-7004-98-1	Event Recorders for Rail Rapid Transit Systems	Locomotive	Design & data collection	Incident & operation/ maintenance
U.S.	Standard	AAR Manual of Standards (MSRP) Standard S-5512	Event Recorders for Locomotives	Locomotive	Design & data collection	Incident
U.S.	Voluntary standard	APTA-RT-VIM-RP-015-03	Recommended Practice for On-Board Recording Equipment Periodic Inspection & Maintenance	All rail modes	Data collection	Incident & operation/ maintenance
U.S.	Voluntary standard	IEEE Standard 1482.1	Standard for Rail Transit Vehicle Event Recorder	All rail modes	Design & data collection	Incident & operation/ maintenance

Appendix B Transit Agency Data Collection Form

Purpose: Transportation Technology Center, Inc. (TTCI) with support from Center for Urban Transportation Research (CUTR) at the University of South Florida was tasked by the Federal Transit Administration (FTA) in researching and developing rulemaking standards for Event Data Recorders (EDRs) for rail transit systems. As part of this effort, TTCI is collecting data from the industry on the use of EDRs.

1.) Agency Name: _____

2.) Rail Mode (s): _____Heavy Rail _____ Light Rail _____Street

3.) Fleet size by Mode: _____Heavy Rail _____ Light Rail _____Street

4.) Number of vehicles equipped with EDR's by mode: _____Heavy Rail _____ Light Rail _____Street

5.) Are there any current rehabilitation projects that include EDR installation? _____

6.) If yes to #5, were any specifications used in the rehabilitation quotation and can you provide specification names?

_____

_____

7.) Are there any current vehicle procurement projects that include EDR's? _____

8.) If yes to #7, were any specifications used in the procurement documents and can you provide specification names?

_____

_____

9.) How do you use EDR data (i.e. incident investigation, operational data, maintenance data, other)?

_____

_____

10.) Why type of data do you collect from the EDR?

_____

_____

11.) How do you download the data? If wirelessly, how is cyber security addressed?

_____

_____

12.) How often do you look at the EDR data? _____

13.) How many employees at your agency understand how to interpret the data from the EDR? _____

14.) Does the EDR data require special software to view? _____

Appendix C Transit Agency Data Collection Results

Rail Transit Agency (43)	Mode*	2007 Study		2017 Study	
		2007 Fleet Size	*2007 Vehicles Equipped*	*2017 Fleet Size*	*2017 Vehicles Equipped*
Rock Region METRO (formerly Central Arkansas Transit Authority [CATA])	LR	5	5	5	0
Bay Area Rapid Transit (BART)	HR	669	0	669	669
Los Angeles County Metropolitan Transportation Authority (LACMTA)	HR	104	0	104	0
	LR	121	0	232	111
San Francisco Municipal Railway (SF MUNI)	LR	181	0	149	0
	Streetcar			50	0
Santa Clara Valley Transit Authority (SCVTA)	LR	101	0	99	0
San Diego Trolley, Inc. (SDT)	LR	134	0	128	0
	Streetcar			2	0
Sacramento Regional Transit District (SRTD)	LR	76	0	97	97
North Country Transit District	LR			12	12
Denver Regional Transportation District (RTD)	LR	83	34	172	172
Miami-Dade Transit (MDT)	HR	136	0	136	0
Hillsborough Area Regional Transit (HART)	LR	10	0	10	0
Metropolitan Atlanta Rapid Transit Authority (MARTA)	HR	316	220	338	338
New Orleans Regional Transit Authority (NORTA)	LR	6	0	66	0
Maryland Transit Administration (MTA-MD)	HR	100	0	100	0
	LR	53	0	53	0
Massachusetts Bay Transportation Authority (MBTA)	HR	408	2	432	94
	LR	239	85	199	93
Metropolitan Council, Hiawatha Metropolitan Transit Light Rail (Hiawatha)	LR	25	25		
St. Louis MetroLink	LR	83	83	87	87
New Jersey Transit – Hudson-Bergen (NJT–HB)	LR	54	54	52	52
New Jersey Transit – Newark City Subway (NJT-NCS)	LR	21	21	21	21
New Jersey Transit – River Line (NJT–RL)	LR	20	20	20	20
Port Authority Transit Corporation (PATCO)	HR	121	0	120	54
New York City Transit (NYCT)	HR	6,202	1,842	6,418	1,492
Greater Cleveland Regional Transit Authority (GCRTA)	HR	60	0	60	60
	LR	48	0	34	0

Rail Transit Agency (43)	Mode*	2007 Study		2017 Study	
		2007 Fleet Size	*2007 Vehicles Equipped*	*2017 Fleet Size*	*2017 Vehicles Equipped*
Tri-County Metropolitan Transportation District of Oregon	LR	105	105	145	145
	HR			4	4
Portland Streetcar (PSC)	LR	7	7	17	17
Southeastern Pennsylvania Transit Authority (SEPTA)	HR	369	0	345	0
	LR	159	0	55	26
	Streetcar			130	0
Port Authority of Allegheny County (PAAC)	LR	83	65	83	83
Tren Urbano (TU)	HR	74	74		
Memphis Area Transit Authority (MATA)	LR	15	0		
Dallas Area Rapid Transit (DART)	LR	107	107	163	163
	Streetcar			4	4
Metropolitan Transit Authority of Harris County (MTA-HC)	LR	18	18	76	76
Galveston Island Transit (GIT)	LR	4	0		
Washington Metropolitan Area Transit Authority (WMATA)	HR	998	476	1,098	559
Utah Transit Authority (UTA)	LR	51	0	117	117
	HR			69	21
	Streetcar			3	3
Sound Transit, King County Metro	LR			62	62
	Streetcar			10	10
Sound Transit, Tacoma Link	LR	3	3	3	3
Kenosha Transit	LR	5	0		
Chicago Transit Authority (CTA)	HR	1,190	0	1,456	714
Niagara Frontier Transit Authority (NFTA)	LR	27	0	27	27
DC Streetcar (DDOT)	Streetcar			6	6
Honolulu Authority for Rapid Transit	LR			0	0
Minnesota Metro Transit	LR			86	86
Loop Trolley Company	Streetcar			3	3
KC Streetcar Program, City of KCMO and KCSA	Streetcar			4	4
Hampton Roads Transit	LR			9	9
Valley Metro Light Rail	LR			50	50
Sun Link StreetCar	Streetcar			8	8
TOTAL		**12,591**	**3,246**	**13,898**	**5,572**

**HR = heavy rail, LR = light rail*

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