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Utilizing Artificial Intelligence with Vision-Based Systems for Monitoring Trespassing – Best Practices

PREPARED BY

Center for Urban Transportation Research
University of South Florida

SEPTEMBER
2023

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Federal Transit Administration

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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 The primary objective of this project was to evaluate the deployment of AI applications with vision-based systems for monitoring trespassing to improve transit safety. AI is a term that encompasses many functions in different systems. For this project, AI refers to all machine vision, computational algorithms, pattern recognition, and other tools applied to data collected specifically with vision- or video camera-based systems in the application of transit safety. As part of the process, online reviews, coupled with stakeholder interviews and surveys, were conducted to reach findings. The review identified vision-based AI applications, existing relevant standards, and areas for standards development to improve the safe operation of public transportation systems.			
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Abstract

The primary objective of this project was to evaluate the deployment of AI applications with vision-based systems for monitoring trespassing to improve transit safety. AI is a term that encompasses many functions in different systems. For this project, AI refers to all machine vision, computational algorithms, pattern recognition, and other tools applied to data collected specifically with vision- or video camera-based systems in the application of transit safety. As part of the process, online reviews, coupled with stakeholder interviews and surveys, were conducted to reach findings. The review identified vision-based AI applications, existing relevant standards, and areas for standards development to improve the safe operation of public transportation systems.

Executive Summary

Trespassing along railroad rights-of-way (ROW) is the leading cause of rail-related fatalities in the U.S. According to Federal Railroad Administration (FRA) data, more than 500 trespassing fatalities and 1,000 casualties (fatalities and injuries) have occurred each year since 2017, with the majority occurring in California, Texas, and Florida. Additionally, the National Transit Database (NTD) hosted by the Federal Transit Administration (FTA) revealed that there were 209 fatalities due to trespassing between 2011 and 2019, which account for 18 percent of all transit rail fatalities in that period. Since trespassing incidents account for a significant percent of total transit rail fatalities, efforts to prevent trespassing are crucial for rail safety improvement.

FTA entered into a cooperative agreement with the Center for Urban Transportation Research (CUTR) at the University of South Florida (USF) to research how artificial intelligence (AI) and vision-based systems can be used to prevent trespassing on railroad properties, identify existing standards and recommended practices to address trespassing 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 system.

The primary objective of this project was to evaluate the deployment of AI applications with vision-based systems for monitoring trespassing to improve transit safety. AI is a term that encompasses many functions in different systems. For this project, AI refers to all machine vision, computational algorithms, pattern recognition and other tools applied to data collected specifically with vision- or video camera-based systems in the application of transit safety. As part of the process, online reviews, coupled with stakeholder interviews and surveys, were conducted to reach findings. The review identified vision-based AI applications, existing relevant standards, and areas for standards development to improve the safe operation of public transportation systems. The summaries of project findings are provided in the next sections.

Summary of AI Applications for Using Vision-Based Solutions for Monitoring and Mitigating Trespassing

The online review revealed that there are several AI applications in the context of trespassing, including the AI algorithm known as Mask R-CNN (which has been effectively used in analyzing big video data in railroad trespassing cases) as well as other video analytics-integrated solutions. Existing documents revealed that AI-based algorithms are available to detect, identify, and categorize various types of events that occur along rail tracks. The concept of using vision-based AI systems for monitoring trespassing could be categorized into three main areas: 1) agency deployments, 2) vendor products, and 3) research studies.

International examples of agency deployments are provided in this report, such as the intruder detection in Melbourne, Australia, and the collaboration between Nokia and Odakyu Electric Railway in Japan involving the use of a machine-learning based AI solution for detecting trespassing at rail crossings and identifying potential issues in real time.

Numerous vendor products that employ AI and vision-based methods and frameworks to mitigate or reduce trespassing incidents are also accessible, including 1) thermal and infrared-based solutions that use AI to identify potential issues at railroad crossings, and 2) machine learning and vision-based solutions, which are tireless solutions, employing deep learning (DL) technology to automate incident detection and reduce false positive detections.

One of the related research studies includes the groundbreaking work conducted at Rutgers University that involved AI and video-based analytics (highlighted previously as Mask R-CNN). Another research study conducted at North Carolina State University considered the use of AI to detect pedestrian incidents in the railroad ROW. Other research explored the use of vision-based and AI systems in the railroad environment. Those studies either suggest the need for improvement in low lighting or some weather conditions, decreasing false positive detection, or the potential to apply similar AI frameworks to mitigate trespassing along the railroad ROW. The CNN algorithm is an example of such a framework, although highly data intensive, which can detect high risk behavior with a high degree of accuracy.

Summary of Stakeholder Input

Input from three types of stakeholders (transit agencies, vendors, and researchers) related to AI applications and the use of AI standards was acquired by the project team. Nine agencies responded to the survey and 44 percent of those agencies confirmed using vision-based systems without the use of AI, in which the system provides video but not analytics. Among the nine respondents, only the Tri-County Metropolitan Transportation District of Oregon (TriMet) was in the process of deploying vision-based AI systems. Further information obtained from the agency survey revealed that many transit agencies use the vision-based systems for safety and operation reasons. Claims management and security were two other objectives of the systems.

The survey results also show that transportation agencies are not currently using standards, guidance documents, or protocols related to vision-based AI systems. However, the two most important areas of standards were indicated by the transit agencies to be beneficial in the future: 1) camera placement and specifications (e.g., field of view, operating temperature, resolution) and 2) detection algorithm accuracy (e.g., false positive rate, false negative rate). On the other hand, 1) data transfer, storage, processing, and communications between devices and 2) visualization and alert output format (i.e., how the detection is delivered to the operations staff) were rated as the least important among the four areas.

Several benefits of vision-based AI systems in the rail environment were highlighted by the agency survey respondents, including less reliance on manpower or minimum requirement of staff presence at stations for surveillance purposes, innovative solutions for intrusion detection, streamlining components of accident/incident/criminal investigations, reducing the likelihood of operator error, and usefulness in claims cases and pay outs. On the other hand, lifecycle costs, funding, user interface, expertise in the field, and strong needs-based stakeholder group were indicated among the challenges and drawbacks of the systems.

Summary of Standards and Protocols

The review conducted as part of this project uncovered various standards related to vision-based and AI systems, including standards related to the selection of camera type for monitoring; detection and video surveillance systems; data output formats; and privacy, robustness, trustworthiness, and licensing of AI systems. However, documents elaborating on the behavior of AI systems, especially vision-based AI systems, are limited. Standards that comprehensively elaborate on the vision-based AI system decision-making process could be useful to transit agencies in the future. Furthermore, many of the identified standards in this report have important aspects that can be collected to make a single and complete implementation guide of vision-based AI systems for monitoring trespassing on railroad properties.

Section 1 Introduction

Trespassing along railroad property is a leading cause of rail-related fatalities in the U.S. Analysis of Federal Transit Administration (FTA) data between 2011 and 2019 discloses that there were 209 fatalities due to pedestrians not in a crossing, walking along the tracks, crossing the tracks, or attempting other kinds of trespassing (FTA, 2019). According to an FRA Report to Congress (FRA 2018), between 2012 and 2017 the annual number of trespass-related pedestrian fatalities increased 18 percent, from 725 people in 2012 to 855 in 2017. These statistics raise serious concerns about the need to mitigate trespassing incidents on railroad properties.

Recognizing the safety risks from trespassing attempts on railroad premises (numerous fatalities and injuries), FTA entered into a cooperative agreement with the Center for Urban Transportation Research (CUTR) at the University of South Florida (USF) to research AI and vision-based systems that can be used to mitigate trespassing incidents, 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 system.

The goal of this project is to assess the utilization of AI with vision-based systems for monitoring trespassing to improve transit safety. AI is a term that encompasses many functions in different systems. For this project, AI refers to all machine vision, computational algorithms, pattern recognition, and other tools applied to data collected specifically with vision-based (camera) systems in the application of transit safety. The project team conducted an online review, agency survey, and stakeholder interviews as part of the process. The report summarizes some AI applications, recognizes needs for standards development, proposes the modification of existing relevant standards, and suggests the creation of new standards to assist with the use of AI with vision-based systems.

After the definitions of terms in this section, the rest of the report is organized as follows: Section 2 covers the background review of AI applications, standards, and protocols, Section 3 summarizes the stakeholder input from the agency survey, and vendor and researcher interviews, Section 4 elaborates on the identified and important standards and protocols as well as gaps in the existing state of practice and standards, and Section 5 synthetizes the findings and conclusions.

Definitions of Terms (AI, Vision-Based Solutions)

The following terms are used throughout this report, and describe the main systems or ideas used to achieve the outcome: detect trespassers and alert rail operators of their presence. Definition of key terms:

- Artificial intelligence (AI) systems enable machines to simulate human intelligence.
- Vision-based systems use cameras or sensors to process and interpret images.
- Vision-based AI systems combine vision or video input and AI algorithms (and other tools) to detect objects (usually humans) and provide real-time alerts to operators.
- Video analytics is the process of analyzing video to detect, determine, and classify temporal and spatial objects or events based on a structured database of information from the raw video. For example, it can be used for motion detection or facial recognition.
- Data analytics is the process of examining, cleaning, transforming, and modeling raw data to uncover patterns, discover useful information, and draw important conclusions.
- Machine learning (ML) – machines can learn from new data without humans interfering.
- Computer Vision (CV) – enable machines to see in the same way humans do, using cameras and other hardware.
- Deep learning (DL) – type of AI that imitates the way the human brain works to process data and patterns.
- Neural Network (NN) – AI framework that is patterned after the neurons of the human brain.
- Convolutional Neural Network (CNN) – special kind of neural network that is designed to process images.

Section 2

Background Review

AI Applications and Pilot Programs Using Vision-Based Solutions for Monitoring and Mitigating Trespassing

An emerging area of applications is to use AI and machine learning techniques to analyze available data to identify patterns and categorize incidents. FRA is examining how AI technologies can be applied to detect trespassers in real time and develop trespass detection algorithms that can be used on both stationary (near the tracks) and mobile platforms [Unmanned Aircraft Systems (UAS), drones]. The results of this review will enable FRA to develop tools necessary to assist the railroad industry and community to identify hot spots and significantly improve trespasser detection.

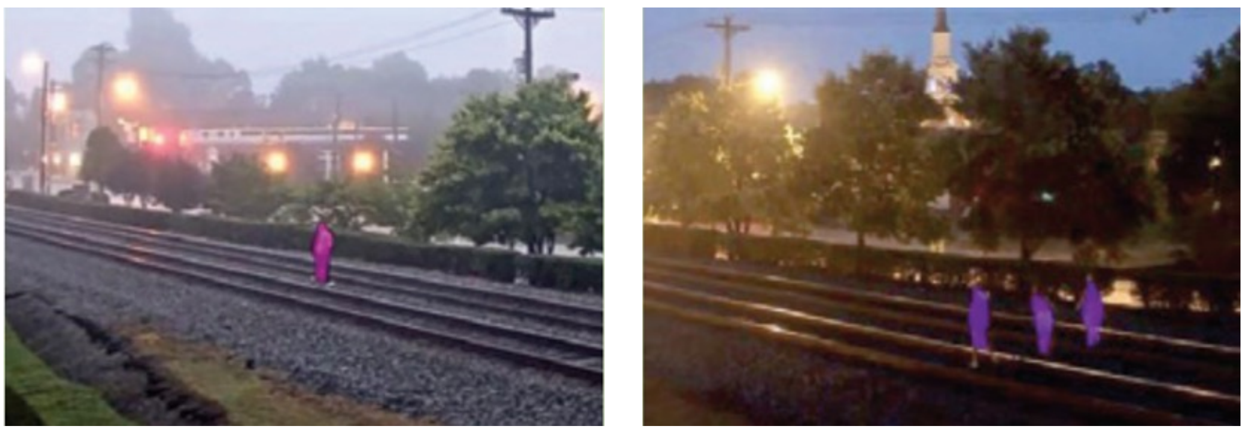
An AI algorithm known as Mask R-CNN has been successfully used in analyzing big video data in railroad trespassing (Zaman et al., 2019). This AI provides a platform for automatically gathering information from railroad live feeds to leverage manual labor in collecting massive data on railroad trespasses. With the advent of this AI technology, this approach helps rail agencies with the laborious task of reviewing the extensive CCTV network. The framework can automatically gather previously inaccessible data on trespassing to inform long term strategic education, enforcement, and engineering solutions. The AI framework for railroad trespasser detection is illustrated in Appendix A.

Vision-based AI technology can provide multiple services to the rail agencies using a suite of video analytics-integrated solutions (Figures 2-1 to 2-4). Possible services include:

- People-counting
- Overcrowding detection
- Crossing the yellow line on platforms
- Crossing rail tracks
- Smoke and fire detection
- Objects on rail tracks and platforms
- Trespassing detection
- Empty carriages detection

Source: Zaman at al. 2019

Figure 2-1 *Trespassing Vehicle Detection – AI-Based Detecting Algorithm*



Source: Zaman at al. 2019

Figure 2-2 *Trespasser Detection – Obstruction on Railroads Using AI-Based Detection Algorithms*

Source: Ai-VU Smart Rail by Aitek

Figure 2-3 *Trespasser Detection – Activity on Rail Track at Railroad Station*

Source: Pearce, 2021

Figure 2-4 *Trespasser Detection – Track Surveillance with Laser Beam in UK*

Video analytics-based solutions have been employed at railroad crossings and tracks to detect trespasser activity as well as other disruptions. Algorithms are created that detect, identify, and categorize various types of events that occur along rail tracks.

Upon reviewing the literature for surveying AI and vision-based systems to monitor trespassing, three major components were found:

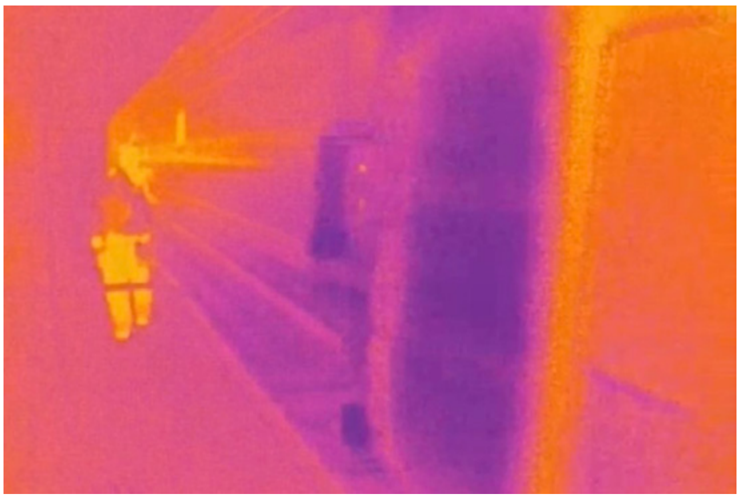
1. **Agency deployments**
2. **Vendor products**
3. **Research studies**

This section outlines the major findings and best practices observed across all three of these components.

Agency Deployments

Metro Trains Melbourne has utilized a combination of optical sensors, thermal imaging, and artificial intelligence to detect trespassers along the rail network in Melbourne, Australia (Pearce, 2021). The intruder detection system, deployed around November 2020, has been successful in capturing CCTV footage of people risking their lives and enhancing the safety of other persons (Ireland, 2021). Although no specific numbers were reported to show the decrease in trespassing since the deployment of the system, the deployment enabled Metro Trains Melbourne to "[run] 93.1 per cent of trains on time – above the 92 per cent target – while 98.5 per cent of scheduled services were delivered, meeting the 98.5 per cent target" (Ireland, 2021).

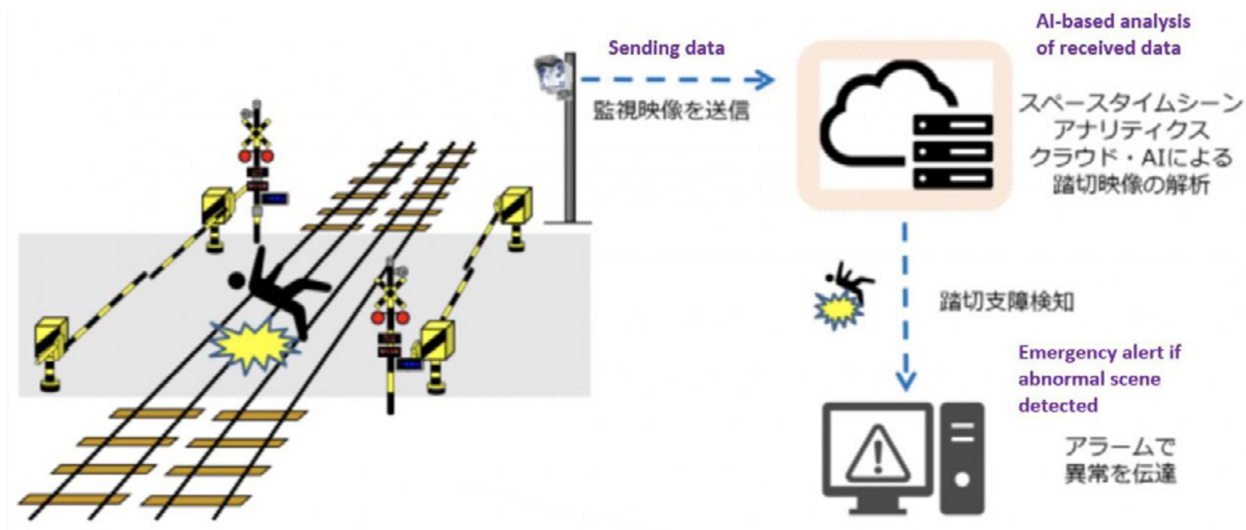
Once there is an activation due to a trespasser, an alert is sent to the Metro Trains network control center, which is then used to alert security teams and the police to help track the location of the event. In addition to this, the rail agency has (1) installed a network of 9,000 CCTV cameras along the stations and on trains across Melbourne, (2) managed a dedicated team of network security and surveillance professionals who routinely patrol hotspots, and (3) carries out joint operations with the Victoria Police (Pearce, 2021). Trespassing incidents have been a grave problem for the rail agency, with a reported average of 328 monthly trespasser incidents across the Melbourne heavy rail network. Figure 2-5 shows how trespassers are detected by the thermal imaging system.



Source: Pearce, 2021

Figure 2-5 *Trespassers Detected by Thermal Imaging – Metro Trains Melbourne*

Odakyu Electric Railway (Japan) collaborated with Nokia to test a machine learning-based artificial intelligence solution for detecting trespassing at rail crossings and identifying potential issues in real time (Robuck, 2020). During the trials that were conducted from February to March of 2020, Nokia's SpaceTime scene analytics was used by the rail agency to identify methods for improving rail crossing safety. As part of the process, machine learning-based artificial intelligence was applied to detect abnormal events to supplement available camera images (refer to Figure 2-6).



Source: AMP, Japan

Figure 2-6 *Nokia SpaceTime Scene Analytics Application for Odakyu Electric Railway*

This type of analysis of image feeds generated by railroad crossing cameras will help Nokia identify potential issues preemptively, thereby enhancing safety around rail crossings (Robuck, 2020). Applications such as this would be very useful for identifying potential conflict zones and preemptively working to alert law enforcement agencies to increase patrolling, as well as for reducing gaps in enforcement and mitigation. No further details of actual deployment of the system beyond testing is available.

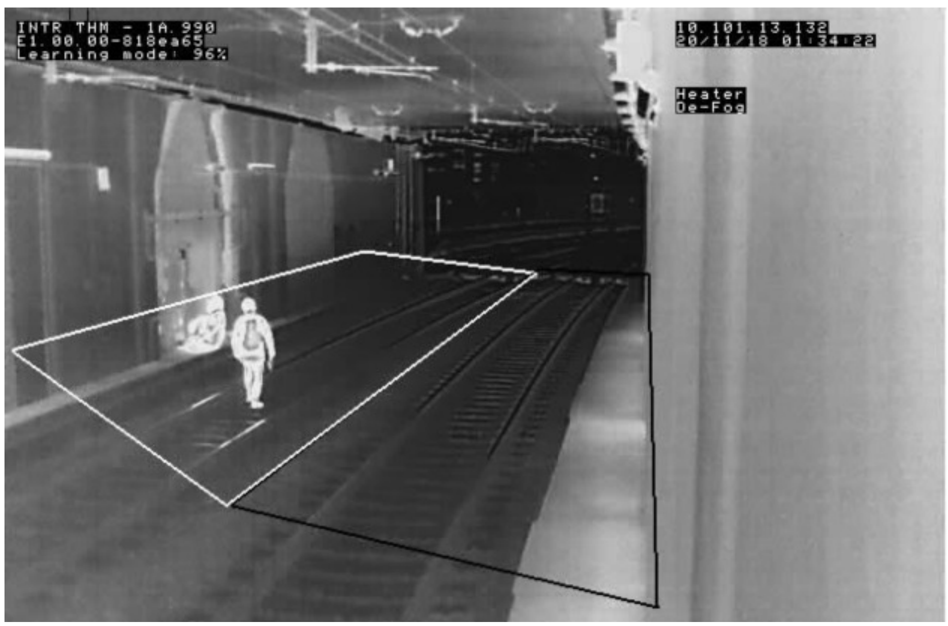
Vendor Products

The CUTR team reviewed several vendor products that employ AI and vision-based methods and frameworks to mitigate or reduce trespassing incidents or other abnormal behavior. This section outlines some of the most used vendor products in this space.

The first category of products are thermal and infrared-based solutions (see Figure 2-7). These products use machine learning-based artificial intelligence frameworks to identify potential issues at railroad crossings. Most of these vendor products involve the use of thermal cameras along with Vehicle-to-Everything (V2X) technology and dedicated algorithms that have the capability to trigger third-party systems (refer to Figure 2-8). These technologies, when deployed correctly, help public transportation systems operate safely and efficiently, keep people safe, and reduce costly delays.

Source: FLIR, 2021

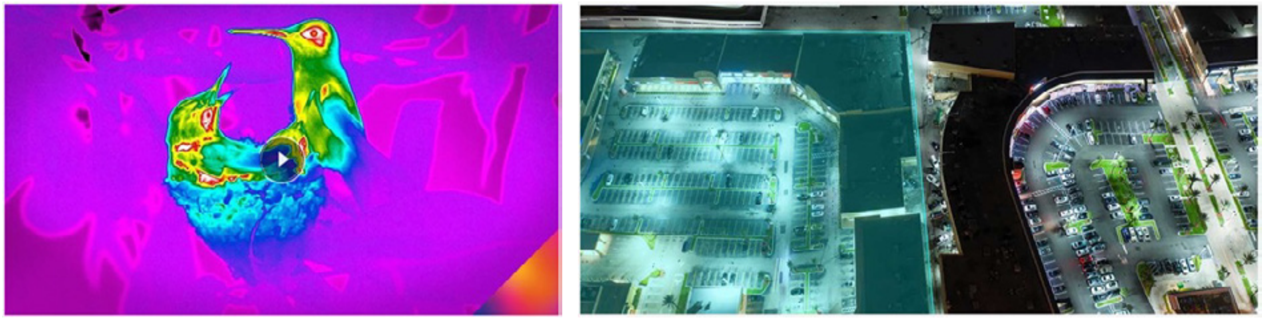
Figure 2-7 *FLIR Thermal Imaging Cameras*



Source: FLIR, 2020

Figure 2-8 *Intrusion Detection Using Thermal Imaging*

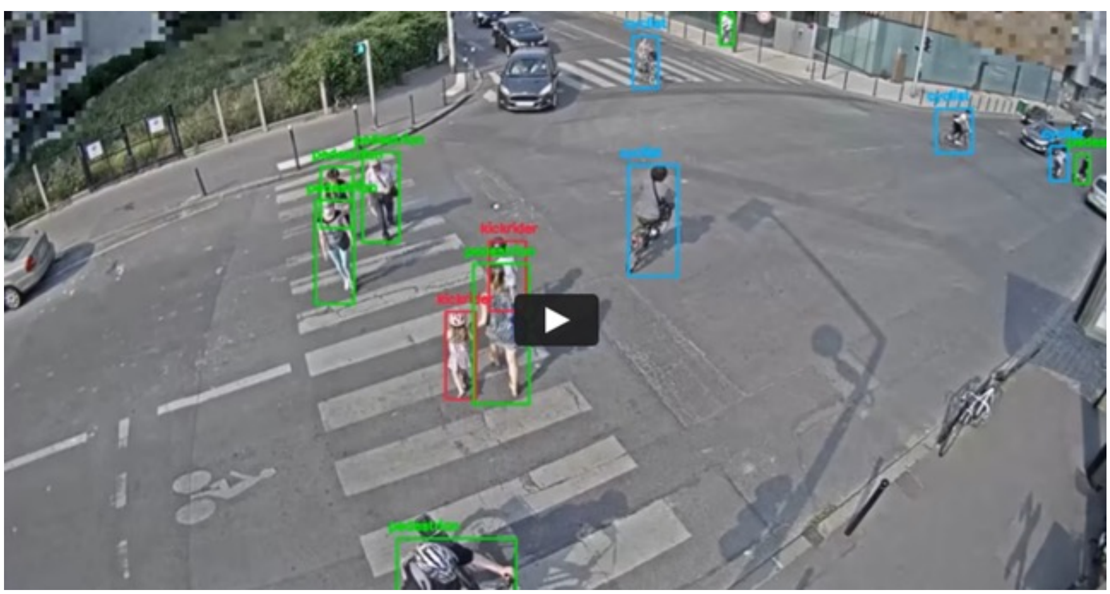
In addition to applications in railroad systems, there are several other products used in other transportation settings that could be utilized for railroad safety enhancement. For instance, San Jose Airport has installed end-to-end perimeter intrusion detection technology (after a thorough review of six different vendor technologies) with the goal of keeping its infrastructure safe from potential threats and abnormal situations.



Source: FLIR, 2021b

Figure 2-9 *Other Applications for Thermal Imaging-Based Systems – Bird Watching and Airport Surveillance*

The second category of vendor products involve learning/vision-based solutions. The advantage of the learning/vision-based solutions is that they are tireless. These products use deep learning (DL) technology that helps to automate incident detection and reduce/eliminate false positive detections. Detecting vulnerable users has been identified as one of the foremost future applications of applied deep learning in mobility (Goldhammer et al., 2019; Chilikuri et al., 2019). A prominent use case in this category is to conduct pedestrian and bicycle detections at intersections (see Figures 2-10 and 2-11). The fundamental idea used for this use case could very well be utilized for trespassing detection and mitigation along railroad systems.



Source: Citilog, 2021

Figure 2-10 *Learning-Based Solution for Pedestrian and Bicyclist Detection*

Source: Miovision, 2021

Figure 2-11 *Detecting Pedestrians and Vehicles in Inclement Weather*

Research Studies

Very few research studies have been conducted on the application of AI and vision-based methodologies to mitigate trespassing incidents along railroads. Among them, some seminal work conducted at Rutgers University attempts to utilize video-based analytics using a developed artificial intelligence framework, known as Mask R-CNN (Zaman, 2018; Zhang et al., 2018; Zaman et al., 2019). This AI-based framework is used to extract video information from big video datasets. This has been applied to select railroad crossings in the state of New Jersey. The AI algorithm can detect trespassing of railroad tracks that are typically categorized as near-miss events. A variety of tools are then utilized to conduct the video analysis. The final solution is packaged into a computer-aided decision support tool known as AI-Grade. Figure 2-12 describes the framework adopted by the researchers.

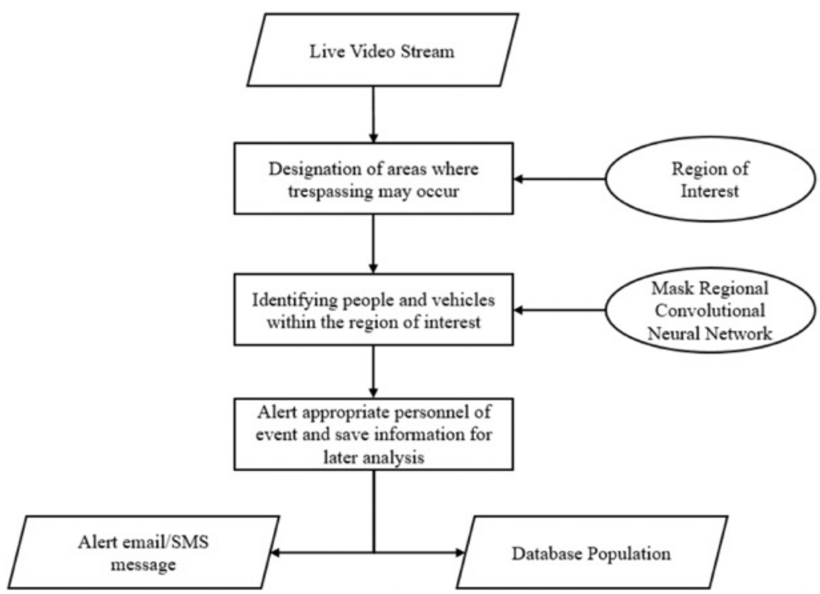
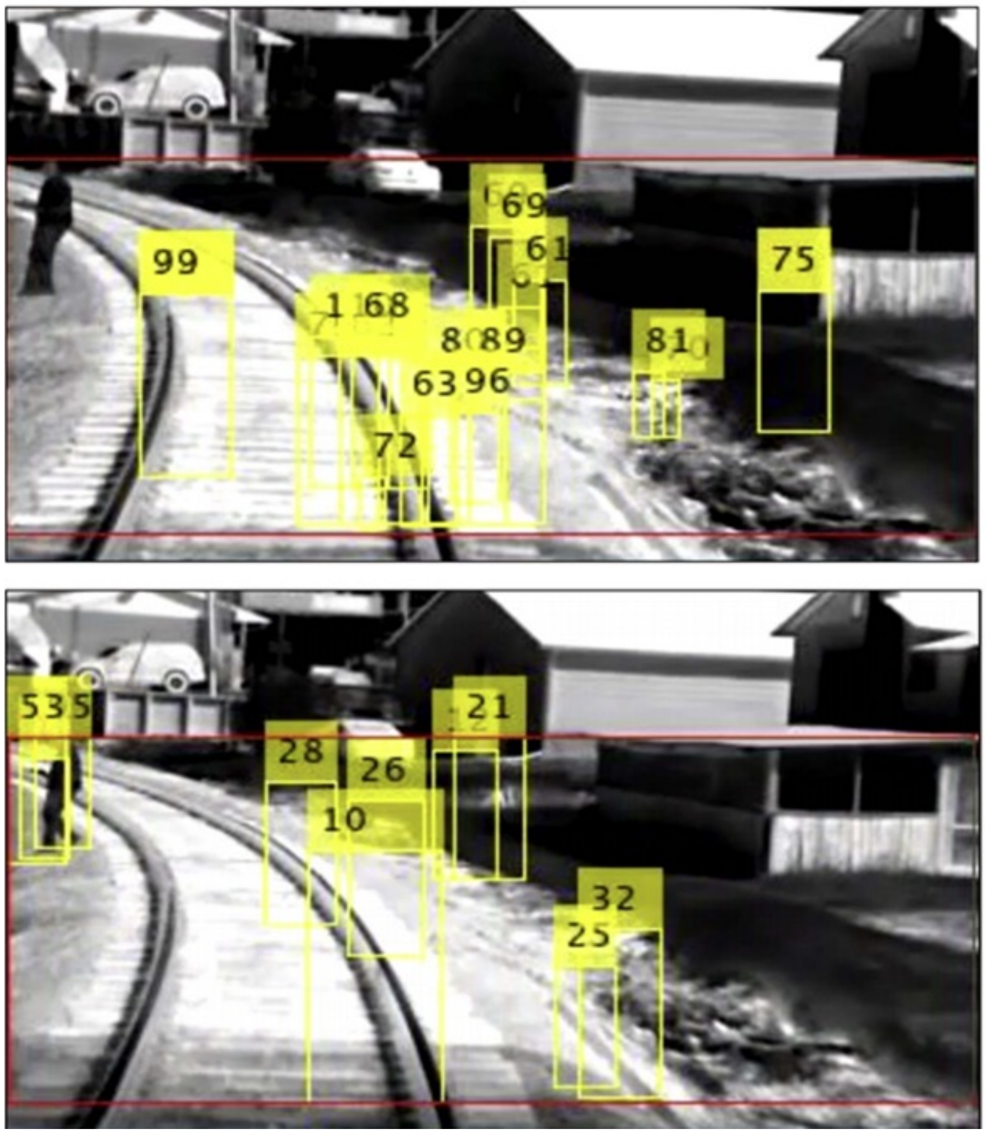


Figure 2-12

AI-Based Framework Adopting Video Analytics for Railroad Safety Research

Source: Zaman, 2018

Researchers from North Carolina State University conducted a study on pedestrian incident detection in the railroad ROW using an artificial intelligence framework (Cunningham et al., 2019). The key objective in this study was to develop a working prototype train-mounted camera system that would be used to capture trespassing events. The researchers utilized a dynamic camera database on a moving train against a static camera database to reduce the number of false positives to a lower confidence level with respect to incident detection (the static camera database produced higher confidence levels for false positive cases). In addition to standard cameras, a thermal camera was used for video input (see Figure 2-13).



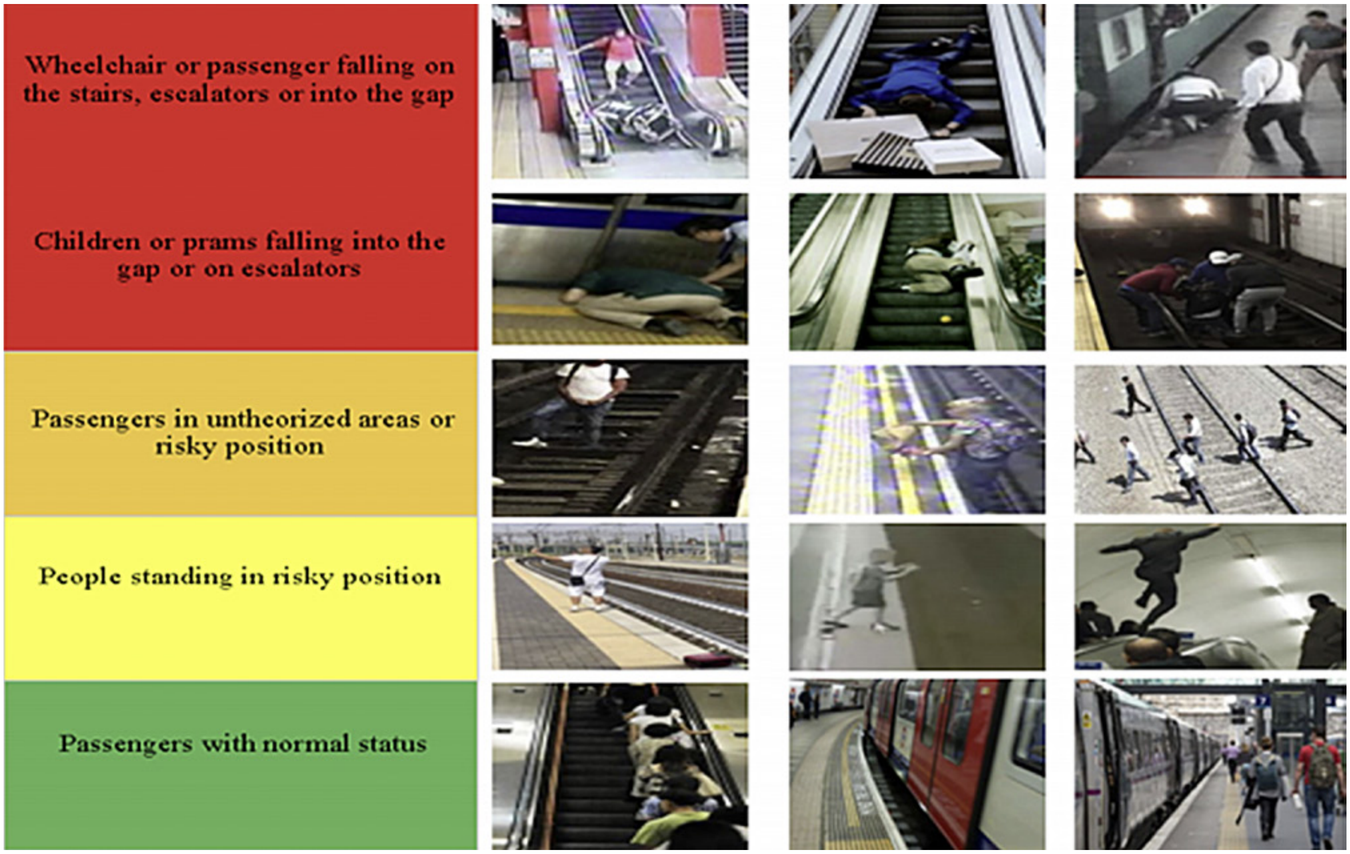
Source: Cunningham et al., 2019

Figure 2-13 *Pedestrian Incident Detection along Railroad Right-of-Way Using AI – top: static camera database; bottom: dynamic camera database*

The machine-learning based AI algorithm developed by the researchers themselves was trained to detect trespassers and pedestrians and it performed better with the dynamic camera database than the static camera database.

A similar study was also conducted by Havens and Lautala (2020) using outward facing locomotive cameras to detect human movement along railroad property in Chicago, IL. Results showed that the typically used low-resolution, front-facing locomotive cameras were unable to perform with complete satisfaction on all rail and person detections, as against the high-definition Metra video streams found on YouTube. Therefore, the lane detection model, according to the authors, needs to be improved to perform better in low lighting scenarios (which maybe typical use cases), improve in terms of false detection rates, and along diverse weather conditions (Havens and Lautala, 2020).

In another study, convolutional neural network (CNN) and deep learning algorithms were utilized to track behavioral change patterns at railway stations (Alawad et al., 2020). The proposed model and the algorithm offered a more beneficial method for obtaining more accurate dynamic data, and detected adverse conditions as soon as possible by capturing fall, slip, and trip (FST) events in the stations that represent high-risk outcomes. The framework of the presented method is generalizable to a wide range of locations and to additional types of risky behaviors, including trespassing along the railroad ROW (refer to Figure 2-14). As stated earlier, the CNN algorithm, although highly data intensive, can detect high risk behavior with a high level of accuracy (Alawad et al., 2020).



Source: Alawad et al., 2020

Figure 2-14 *Clusters of Risky Passenger Behaviors at Railway Stations*

Standards and Protocols

This section elaborates on findings from an online search of standards and protocols relevant to AI and vision-based systems. Standards and protocols are separated into two main categories: 1) standards and protocols in transit industry, and 2) standards and protocols in other industries. The main categories were later classified into sub-categories: 1) definitions, key terms, concepts, terminology, 2) monitoring, sensing, object and event detection and response, 3) data and 4) AI systems and algorithms. In addition to standards and protocols in the U.S., international standards and protocols were also reviewed. Since most of the standards were not free of charge, further details than the summary were not readily available. It is important to note that the standards are reviewed every 5 years; therefore, additional details on each identified standard (i.e., publication date and links) are provided in Appendix B.

Transit Safety Standards, Recommended Practices, and Protocols

Although no standard could be identified in the transit industry directly related to AI, a few standards were available related to vision-based, audio-based, communication, and other intelligent systems. The organizations that published those relevant transit standards, recommended practices, guidance, and protocols include the American Public Transportation Association (APTA), the Association of American Railroads (AAR), the Institute of Electrical and Electronic Engineers (IEEE), and the Rail Safety and Standards Board (RSSB). A summary of the standards, recommended practices, guidance, and protocols are included in Table 2-1.

Table 2-1 *Transit Standards Related to Vision-Based and Other Intelligent Systems*

Document Title/Number/Link	Summary
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	Provides selection guidelines for cameras in fixed and mobile systems on trains or other transit environment. The practice can ensure good quality images, recordings, and network systems are used within transit-related CCTV systems.
APTA RT-OP–RP-024-19 Crash and Fire Protected Inward and Outward Facing Audio and Image Recorders in Rail Transit Operating Compartments	Summarizes minimum requirements for selection, installation, operating and maintenance requirements for crash and fire protected inward- and outward-facing audio and image recorders in all rail transit vehicle operating compartments. Enables collection of important data for investigating accidents and managing the safe operations of trains.
APTA BTS-BRT-RP-005-10 Implementing BRT Intelligent Transportation Systems	Guides transit agencies by documenting types of ITS that can be considered for bus rapid transit (BRT) and underlines best practices and examples. Covers the integration of the ITS elements into the building, operating, and maintaining of BRT services and infrastructure. This recommended practice can be adapted for rail systems and for monitoring trespassing using AI.
APTA RT-VIM-S-026-12 Rail Transit Vehicle Passenger Emergency Systems	Provides recommended practices, guidelines, and requirements for various passenger emergency systems for new rail transit vehicles.
IEEE 1473 An open-source communications protocol for railway vehicles	Includes two variants, the type T and L standards that integrate safe default behavior into message responses. Improves safety and reliability of rail systems. For further reliability and safety, Type T provides for freshness monitoring, while type L offers heartbeat monitoring to ensure that network data are valid. Freshness monitoring involves timestamping of the data. In contrast, heartbeat monitoring involves using the system clock to ensure that essential functions continue to run. The system uses Manchester encoding and cyclic redundancy checking on the packets to ensure their integrity.

Document Title/Number/Link	Summary
IEEE 1474.4-2011 IEEE Recommended Practice for Functional Testing of a Communications-Based Train Control (CBTC) System	Summarizes recommended methods for functional testing of a communications-based train control (CBTC) system, based on the CBTC system design and functional allocations.
RIS-2712-RST Iss 1 On-Train Camera Monitoring Systems	Elaborates on the use of modern camera systems for the purposes of recording, storing, and accessing video data from rolling stock. Contains guidance on methods to protect the camera systems and data storage from physical or cyber unauthorized access, and what the British Transport Police needs when using the recorded data as part of an investigation.

In the standard, guidance, and protocol documents, further details are provided on specifications and recommendations. Although providing details related to specifications and recommendations is not the objective of this project, a couple of examples are highlighted below to provide directions for future research. For example, Table 2-2 includes screen image specifications for the selection of cameras for a transit system from APTA (APTA-IT-CCTV-RP-001-11). According to the specifications, depending on the goal and application of the camera (i.e., detect, monitor, recognize, and identify), a particular screen image is recommended. Similarly, Table 2-3 expands on frame rate recommendations. For low-traffic pedestrian areas and boundary/perimeter fences, a minimum of five frames per second is recommended. Additionally, a minimum of 15 frames per second is suggested for trackside operations and platform areas.

Table 2-2 *Screen Image Specifications by Function*[1]

Source: APTA, 2011

Function[2]	Screen Image[3]	Typical Applications[4]
 Detect	**Not less than 5 percent:** A figure occupies at least 5 percent of the screen height. From this level of detail, an observer should be able to monitor the number, direction, and speed of movement of people, providing their presence is known.	**Perimeter security:** Long-range images over parking lots, etc.
 Monitor	**Not less than 10 percent:** The figure now occupies at least 10 percent of the available screen height. After an alert, an observer would be able to search the display screens and ascertain with a high degree of certainty whether a person is present.	**Entrance areas:** Medium-range perimeter security. Medium-range security of entrance halls, platform areas, etc.
 Recognize	**Not less than 50 percent:** When the figure occupies at least 50 percent of screen height, viewers can say, with a high degree of certainty, whether or not an individual shown is the same as someone they have seen before.	**Mobile applications:** Interior car and bus surveillance at door or call button areas. Front-facing applications on vehicles or areas where bus or train exteriors are viewed. Short-range security for hallways, revenue and ticket areas, railroad crossings, call buttons, parking garage entrances/exits and elevator lobbies.
 Identify	**Not less than 120 percent:** With the figure occupying at least 120 percent of the screen height, picture quality and detail should be sufficient to enable the identity of an individual to be established beyond a reasonable amount.	**Mobile applications:** Cash boxes, fare machines for crew safety. Short-range applications at ticket barriers, fare machines, cash rooms, garage barriers, and secure door entrances (license plate and payment machine).

1. Use of PTZ cameras should be configured to give maximum resolution over the most demanding requirements. Number plate recognition will be achieved using not less than 50% of screen height for a car.
2. Screen height representations are not to scale and are for illustration only.
3. Screen image is defined as the size of an image when viewed on a monitor without zoom.
4. Applications are given as an example only, as specific areas will vary according to local conditions.

Table 2-3 *Summary of Frame Rate Recommendations*

Source: APTA, 2011

Area to be Observed	Minimum Frames Per Second[1]	Minimum Resolution
Low-traffic pedestrian areas and boundary/perimeter fences	5(4)	4CIF/D1
Trackside operations and platform areas	15 (12)	4CIF/D1
Access control	5 (4)	4CIF/D1
Ticket office desks and pay machines	15 (12)	4CIF/D1
Vehicle traffic areas, parking garages, or forward-facing cameras on trains, trams and buses	30 (25)	4CIF/D1 (progressive scan) Mobile platforms only may use 2CIF[2]
On-vehicle passenger areas	5 (4)	4CIF
Vehicle passenger areas when emergency call operated or in the area of doorways	15 (12)	4CIF

1. Recommendations for PAL-based systems in parenthesis.
2. Due to the implementation of various interlacing schemes between 2CIF and 4CIF it is permissible to use the 2CIF setting of a 4CIF camera for cameras observing moving objects. When interlaced video is digitized, it is acceptable to digitize only the off *or* even lines and extrapolate the other lines. It has been demonstrated that this methodology improves the resolution of the video on playback and also reduces storage requirements. Therefore, this method would be limited for use on mobile platforms only.

CIF: Common Intermediate Format measurement designed to convert to PAL (Phase Alternating Line) or NTSC (National Television Standards Committee) analog video standards. CIF defines a video image with a resolution of 352x288 exactly like a standard PAL source input format.

AI-Related Standards in other Industries

AI and vision-based systems are available in other industries. For example, several voluntary technical standards relevant to vehicle automation (USDOT, 2018) are also applicable when using AI and vision-based systems to monitor trespassing. The sources of AI and vision-based systems standards, guidance, and protocols comprise: the National Institute of Standards and Technology (NIST), the Society of Automotive Engineers (SAE International), the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and Electrical and Electronic Engineers Standards Association (IEEE SA). The relevant standards for using AI and vision-based systems for monitoring trespassing can be classified into various categories as illustrated in Figure 2-15. Communication and system security standards could also be applicable.

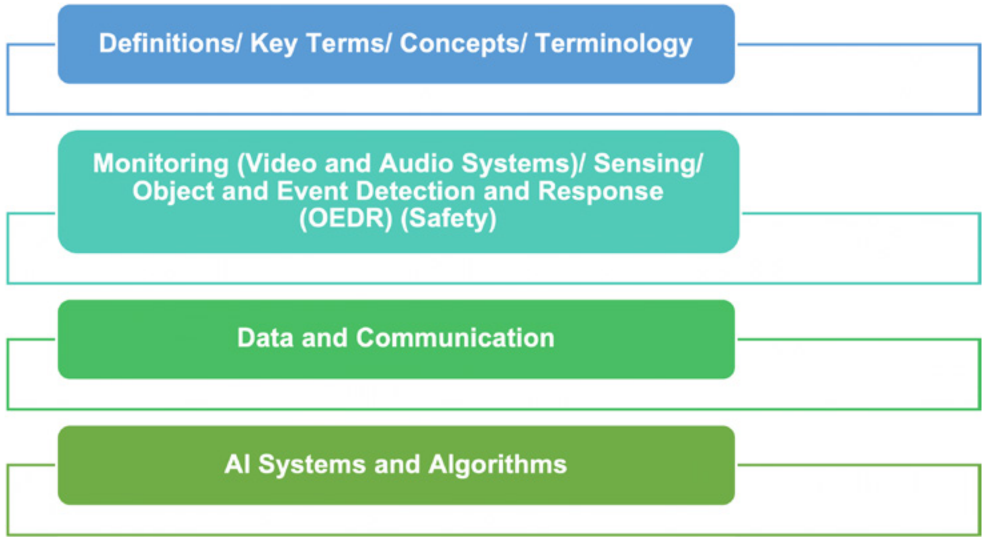


Figure 2-15 *Categories of AI Related Standards Relevant to Monitoring Trespassers*

Definitions/Key Terms/Concepts/Terminology

The definitions and key terms standards focus on defining concepts and terminology. A few identified standards in that category elaborated on automated and safety standards. The two standards are synthetized in Table 2-4.

Table 2-4 *Definitions, Key Terms, Concepts, Terminology for AI Relevant Standards*

Document Title/Number/Link	Summary
SAE J2396_201705 Definitions and Experimental Measures Related to the Specification of Driver Visual Behavior Using Video Based Techniques	For consistency, it includes definitions of key terms in evaluating video-based driver eye glance behavior and data. It can also assist when assessing the capability of automated sensors (eye trackers) and automated reduction (computer vision).
SAE J3088 Active Safety System Sensors	It defines the functionality and performance of active safety sensors.

Monitoring (Video and Audio Systems)/Sensing/Object and Event Detection and Response (OEDR) (Safety)

Monitoring, sensing, and detecting are important for vision-based AI systems. Several international standards are available related to video and audio systems. Table 2-5 lists numerous examples of such standards.

Table 2-5 *Standards Related to Monitoring, Sensing, Object and Event Detection and Response (Safety) (Other Industries)*

Document Title/Number/Link	Summary
ISO 19237:2017 Intelligent Transport Systems—Pedestrian detection and collision mitigation systems (PDCMS) — Performance requirements and test procedures	Indicates the concept of operation, minimum functionality, system requirements, system interfaces, and test procedures for Pedestrian Detection and Collision Mitigation Systems (PDCMS). Indicates recommended behaviors for PDCMS. PDCMS detect pedestrians in advance and alert the driver in case of danger. The systems also determine if the danger can be avoided.
ISO 22839:2013 Intelligent Transport Systems— Forward vehicle collision mitigation systems — Operation, performance, and verification requirements	Describes the concept of operation, minimum functionality, system requirements, system interfaces, and test methods for Forward Vehicle Collision Mitigation Systems (FVCMS). Indicates recommended behaviors for FVCMS. FVCMS detect hazard in advance and alert the driver. The systems also help determine if the hazard can be avoided.
SAE J3116_201706 Active Safety Pedestrian Test Mannequin Recommendation	Helps develop standard specifications/requirements for pedestrian test mannequins (1 adult and 1 child) that are representative of real pedestrians to the sensors used in pedestrian detection systems and can be used for performance assessment of such in-vehicle systems (including warning and/or braking) in real world test scenarios/conditions.
J3155 Camera Monitor Systems Test Protocols and Performance Requirements	It highlights test protocols with performance requirements for camera monitor systems to replace existing statutorily required inside and outside rear-view mirrors for U.S. market road vehicles.
J3157_201902 Active Safety Bicyclist Test Targets Recommendation	It helps develop standard specifications/requirements for bicyclist test mannequins (one adult and one child) that are representative of real bicyclists to the sensors used in bicyclist detection systems and can be used for performance assessment of such in-vehicle systems (including warning and/or braking) in real world test scenarios/conditions. It provides the recommended bicyclist mannequin characteristics for vision, Lidar, and/or 76 to 78 GHz radar-based bicyclist pre-collision systems.
NIST NISTIR 6910 4D/RCS Version 2.0: A Reference Model Architecture for Unmanned Vehicle Systems	Offers a reference model for military unmanned vehicles on identifying and organizing software components. Offers well defined and highly coordinated sensory processing, world modeling, knowledge management, cost/benefit analysis, behavior generation, and messaging functions, as well as the associated interfaces.
ISO/DIS 20035 Intelligent Transport Systems — Cooperative adaptive cruise control (CACC) —Operation, performance, and verification requirements	Covers two types of cooperative adaptive cruise control (CACC): V2V, and I2V. Both kinds of CACC system require active sensing using, for example, radar, lidar, or camera systems.
SAE J2980_201804 Considerations for ISO 26262 Automotive Safety Integrity Levels (ASIL) Hazard Classification	Includes method and example results for determining the Automotive Safety Integrity Level (ASIL) for automotive motion control electrical and electronic (E/E) systems. Restricted to collision-related hazards associated with motion control systems.

Document Title/Number/Link	Summary
ISO 22840:2010 Intelligent Transport Systems —Devices to aid reverse ma-neuvers — Extended-range backing aid (ERBA) systems	Summarizes backing aid functionality over an extended area located behind vehicle using sensors for detection and ranging to inform the driver about the distance to obstacles.
ISO 17386:2010 Transport information and control systems — Maneuvering Aids for Low-Speed Operation (MALSO) — Performance requirements and test procedures	Covers minimum functionality requirements of the device, such as information on the presence of relevant obstacles within a defined short detection range.
SAE J2945/X Dedicated Short Range Communication (DSRC) Systems	Offers information exchange between a host vehicle and another DSRC enabled device, a device worn by or otherwise attached to a traveler, a roadside device, or a management center, to address safety, mobility, and environmental system needs.
IEC 62676-2-2 : 1ED 2013 Video Surveillance Systems for Use in Security Applications - Part 2-2: Video Transmission Protocols – IP Interoperability Implementation Based on HTTP and Rest Services	Describes the video transmission protocols based on HTTP and rest services.
IEC 62676-4 : 1ED 2014 Video Surveillance Systems for Use in Security Applications – Part 4: Applications Guidelines	Provides recommendations and requirements for the selection, planning, installation, commissioning, maintaining, and testing video surveillance systems (VSS) comprising image capture device(s), interconnection(s), and image handling device(s), for use in security applications.
ASTM D 8205 : 2020 Standard Guide for Video Surveillance System	Includes recommended video surveillance system for protecting waste, currency, people, property, and assets.
AS/NZS IEC 62676.3:2020 Video surveillance systems for use in security applications Analog and digital video interfaces	Describes physical, electrical and software interface (non-IP) specifications of analogue and digital video interface in video surveillance systems (CCTV) applications. Video interfaces are used both for connection and transmission of surveillance video, audio, and control signals. Through video interfaces, video surveillance systems can be put together by connection various components such as image capturing devices, image handling devices, etc. This standard ensures interoperability among various video surveillance components.
AS/NZS 62676.5:2020 Video surveillance systems for use in security applications Data specifications and image quality performance for camera devices (IEC 62676-5:2018, MOD)	Used in Australia and New Zealand, covers requirements for description of video surveillance camera specification items and measurement methods of video surveillance camera specification items.
AS/NZS 62676.2.1:2020 Video surveillance systems for use in security applications Video transmission protocols - General requirements (IEC 62676-2-1:2013, MOD)	Used in Australia and New Zealand, introduces an IP network interface for devices in surveillance applications. It specifies a network protocol for the full interoperability of video devices.

Document Title/Number/Link	Summary
DS/EN IEC 62676-2-31:2019 Video surveillance systems for use in security applications – Part 2-31: Live streaming and control based on web services	Defines procedures for communication between network video clients and video transmitter devices.
AS/NZS 62676.1.2:2020 Video surveillance systems for use in security applications System requirements - Performance requirements for video transmission (IEC 62676-1-2:2013, MOD)	Used in Australia and New Zealand, summarizes general requirements on video transmission on performance, security, and conformance to basic IP connectivity, based on available, well-known, international standards.
CEI EN 50132-7 : 2014 Alarm Systems – CCTV Surveillance Systems for Use in Security Applications – Part 7: Application Guidelines	Provides recommendations and requirements for the selection, planning, installation, commissioning, maintaining, and testing of CCTV systems comprising image capture device(s), interconnection(s), and image handling device(s), for use in security applications.
BS EN IEC 62676-6 Video surveillance systems for use in security applications. Part 6. Video content analytics. Performance testing and grading	Specifies the functions, performance, interfaces, environmental adaptability, test methods, performance evaluation and grading rules of real-time intelligent video analysis in surveillance systems.
NEN EN 50132-4-1 : 2001 Alarm Systems – CCTV Surveillance Systems – Part 4-1 Black and White Monitors	Specifies the minimum requirements for the specification and testing of black and white video monitors used in 625-line CCIR standard closed-circuit television (CCTV) surveillance systems for security applications.

Data and Communication

The use of data is often an important part of AI systems. A couple of data-related standards/recommended practices were identified and included in Table 2-6. It covers common data output formats that can be used to evaluate various conditions based on trigger threshold criteria. Data privacy is also a crucial standard for AI systems that is summarized in Table 2-6.

Table 2-6 *Data Related Standards Relevant to AI*

Document Title/Number/Link	Summary
J3197_202004 Automated Driving System Data Logger	Gives common data output formats and definitions for a variety of data elements useful for assessing automated driving system (ADS) during an event that meets the trigger threshold criteria specified. Aims to enable the use of data from sensors such as camera(s), LiDAR(s) etc. in the absence of a human driver.
SAE J1698 Event Data Recorder (EDR)	Offers common data output formats and definitions for a variety of data elements that may be useful for analyzing vehicle crash and crash-like events that meet specified trigger criteria.

Document Title/Number/Link	Summary
IEEE P7002 – 2022 IEEE Draft Standard for Data Privacy Process	Describes requirements for a systems/software engineering process for considering privacy when dealing with personal data. Enables compliance test with specific privacy practices by using specific procedures, diagrams, and checklists. Provides a use case and data model using products, systems, processes, and applications that involve personal information.

AI Systems and Algorithms

Standards and recommended practices exist covering various aspects of AI systems. The aspects include safety, transparency, accountability, responsibility, system diagnosis, risks related robustness, system trustworthiness, ethical matters, and bias. Those standards are summarized in Table 2-7.

Table 2-7 *AI Systems/Algorithms Related Standards*

Document Title/Number/Link	Summary
AIR6994 Use Case AIR	Summarizes AI technologies, architecture, validation approach, and safety concerns for each use case.
IEC 62243:2012 Artificial Intelligence Exchange and Service Tie to All Test Environments (AI-ESTATE)	Covers formal specifications for supporting system diagnosis. These specifications support the exchange and processing of diagnostic information and the control of diagnostic processes.
ISO/IEC PRF TR 24029-1 Artificial Intelligence (AI) -- Assessment of the robustness of neural networks	Summarizes approaches available to evaluate risks related to the robustness of AI systems, especially risks related to neural networks.
ISO/IEC TR 24028:2020 Information technology -- Artificial intelligence -- Overview of trustworthiness in artificial intelligence	Summarizes subjects related to trustworthiness in AI systems, including approaches to establish trust in AI systems through transparency, explainability, controllability, etc. Also includes engineering pitfalls; typical associated threats and risks to AI systems; possible mitigation techniques and methods; and approaches to evaluate and achieve availability, resiliency, reliability, accuracy, safety, security, and privacy of AI systems.
IEEE P2817 Guide for Verification of Autonomous Systems	Helps in setting up a customized process for verification of an autonomous system based on available resources. It covers best practices across all levels of abstraction within a given system and summarizes a conceptual model that assists in the development of new verification processes for autonomous systems and provides both integration guidance for developing a verification process and techniques, methodologies, and tool types supporting verification process development.

Document Title/Number/Link	Summary
IEEE P3333.1.3 Standard for the Deep Learning-Based Assessment of Visual Experience Based on Human Factors	Describes deep learning-based metrics of content analysis and quality of experience (QoE) assessment for visual contents, which is an extension of Standard for the Quality of Experience (QoE) and Visual-Comfort Assessments of Three-Dimensional (3D) Contents Based on Psychophysical Studies (IEEE STD 3333.1.1)) and Standard for the Perceptual Quality Assessment of Three Dimensional (3D) and Ultra High Definition (UHD) Contents (IEEE 3333.1.2).
ISO/IEC WD 22989 Artificial Intelligence Concepts and Terminology	Will cover AI concepts and Terminology.
ISO/IEC WD 23053 Framework for Artificial Intelligence (AI) Systems Using Machine Learning (ML)	Will provide framework for AI Systems Using Machine Learning (ML).
ISO/IEC NP TR 24027 Information technology — Artificial Intelligence (AI) — Bias in AI systems and AI aided decision making	Will cover bias in AI systems and AI based decision-making.
ISO/IEC NP TR 24030 Information technology — Artificial Intelligence (AI) — Use cases	Provides a collection of representative use cases of AI applications in a variety of domains.
IEEE P2247.1 Standard for the Classification of Adaptive Instructional Systems	Describes and categorizes the elements, functionality, and parameters of adaptive instructional systems (AIS). Provides requirements and guidance for the use and measurement of these parameters.
IEEE P2247.2 Interoperability Standards for Adaptive Instructional Systems (AISs)	Describes interactions and exchanges among the components of adaptive instructional systems (AISs). Describes the data, data structures, and parameters used in these interactions and exchanges. Provides requirements and guidance for the use and measurement of the data, data structures, and parameters.
IEEE P2247.3 Recommended Practices for Evaluation of Adaptive Instructional Systems	Describes and categorizes methods for assessing adaptive instructional systems (AIS) and provides guidance for the use of these methods. Includes principles of ethically aligned design for the use of artificial intelligence (AI) in AIS.
IEEE P2247.4 Recommended Practice for Ethically Aligned Design of Artificial Intelligence (AI) in Adaptive Instructional Systems	Summarizes ethical matters and recommends best practices in the design of artificial intelligence as used by adaptive instructional systems.

Document Title/Number/Link	Summary
IEEE 2660.1-2020 Recommended Practice for Industrial Agents: Integration of Software Agents and Low-Level Automation Functions	Describes best practices to solve the interface problem when integrating intelligent software agents with low-level automation devices in the context of cyber-physical systems. Provides a method to select the best interfacing practice for a given application scenario specified by the user from a library of available interfacing templates and technologies to improve reuse, consistency, and transparency in the integration of industrial agents and low-level control functions.
IEEE P2671 Standard for General Requirements of Online Detection Based on Machine Vision in Intelligent Manufacturing	Uses machine vision to provide requirements for data format, data transmission processes, definition of application scenarios and performance metrics for evaluating the effect of online detection deployment.
IEEE P2830 IEEE Draft Standard for Technical Framework and Requirements of Trusted Execution Environment based Shared Machine Learning	Provides a framework and architectures for machine learning in which a model is trained using encrypted data that has been aggregated from multiple sources and is processed by a third-party trusted execution environment. Describes functional components, workflows, security requirements, technical requirements, and protocols.
IEEE P2840 Standard for Responsible AI Licensing	Describes specifications for the factors that shall be considered in the development of a responsible artificial intelligence (AI) license.
IEEE P2863 Recommended Practice for Organizational Governance of Artificial Intelligence	Defines governance criteria, including safety, transparency, accountability, responsibility, bias, and steps for effective implementation, performance auditing, training and compliance in the development or use of artificial intelligence within organizations.
IEEE P2894 Guide for an Architectural Framework for Explainable Artificial Intelligence	Specifies an architectural framework and application guidelines that enables the adoption of explainable artificial intelligence (XAI), including: 1) description and definition of explainable AI, 2) the categories of explainable AI techniques; 3) the application scenarios for which explainable AI techniques are needed, 4) performance evaluations of XAI in real application systems.
IEEE P7000 Draft Model Process for Addressing Ethical Concerns During System Design	Provides processes to include and evaluate traceability of human ethical values during concept exploration, development, and system design.
IEEE P7001 Draft Standard for Transparency of Autonomous Systems	Depicts measurable and testable levels of transparency to evaluate autonomous systems and their levels of compliance.
IEEE P7003 Algorithmic Bias Considerations	Summarizes specific methods to assist users certify how they worked to address and eliminate issues of negative bias in the creation of their algorithms, including 1) the usage of overly subjective or uniformed data sets or information known to be inconsistent with legislation protected groups (i.e., race, gender, sexuality, etc.); 2) bias against groups not necessarily protected explicitly by legislation, but otherwise diminishing stakeholder or user well-being, 3) application boundaries bias creating unintended consequences arising from out-of-bound application of algorithms; 4) bias due to incorrect interpretation of systems outputs by users (e.g. correlation vs. causation)

Document Title/Number/Link	Summary
IEEE P7008 Standard for Ethically Driven Nudging for Robotic, Intelligent and Autonomous Systems	"Nudges" as exhibited by robotic, intelligent, or autonomous systems are defined as overt or hidden suggestions or manipulations designed to influence the behavior or emotions of a user. Describes typical nudges (currently in use or that could be created). It contains concepts, functions, and benefits necessary to establish and ensure ethically driven methodologies for the design of the robotic, intelligent, and autonomous systems.
IEEE P7009 Standard for Fail-Safe Design of Autonomous and Semi-Autonomous Systems	Creates a practical, technical baseline of specific methodologies and tools for the development, implementation, and use of effective fail-safe mechanisms in autonomous and semi-autonomous systems. Summarizes procedures for measuring, testing, and certifying a system's ability to fail safely on a scale from weak to strong and provides instructions for improvement in the case of unsatisfactory performance.
IEEE 7010-2020 Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being	Measures the impact (especially positive outcome) of artificial intelligence or autonomous and intelligent systems (A/IS) on humans using valid well-being indices. Includes product development guidance, identification of areas for improvement, risk management, performance assessment, and the identification of intended and unintended users, uses and impacts on human well-being of A/IS.

Section 3

Stakeholder Input

The project team collected data inquiring about the use of vision-based or AI systems from three types of entities: 1) transit agencies, 2) vendors, and 3) researchers. As part of the data collection efforts, information was obtained on the various applications of those systems, including safety, operation, and management, and whether the systems are applicable to the railroad environment. Overall, the aim of this data collection task was to identify successful utilization of vision-based or AI systems that could be replicated or adapted by transit agencies to monitor trespassing. Based on the nature of the questions, different data collection techniques were used. For example, an online survey questionnaire was developed for transit agencies while both vendors and researchers were interviewed in person by the project team using pre-defined questions. The following sections elaborate on the survey and interview questions and the summary of findings. The questions and summary of findings are provided separately for each group. In addition to the type of organization, the name of the respondent and contact information were also noted.

Transit Agencies

The survey questionnaire was developed to solicit information on current practices, future deployments and challenges faced by transit agencies. The survey was sent to safety and/or operation managers to the transit agencies that are members of the CUTR Standards Working Group. The survey questions used are shown below.

Survey Questions

1. **Has your agency deployed any vision-based systems?**
    a. Yes or No
    b. If Yes
        i. Do these systems have video or data analytics capabilities?
        ii. Do these systems have AI applications?
        iii. Please describe the systems (short/medium description)
        iv. When did your agency deploy the systems? (year)
        v. Where did your agency deploy the systems (location, description of the setting)?
    c. If No
        i. Would you like or are you planning to use any vision-based systems in the future?
        ii. Why would you be interested in the vision-based systems in the future?

iii. Which kind of vision-based systems would you be interested in? With video analytics capabilities, With AI Application, or other explain.
iv. What would be your goals when deploying the systems (i.e., safety, operation, maintenance, etc.)?
v. What is currently preventing you from deploying the systems?
vi. Would you use or benefit from standards, guidance documents, or protocols when deploying vision-based or AI systems?
vii. If you are already planning, have you identified any standards, guidance documents, or protocols for your planned deployment?
viii. If yes, please describe the standards, guidance documents, or protocols
ix. Do you know of any peer agencies that have successfully used vision-based or AI systems that the project team could learn from?
x. Please provide the names and contact info of the peer agencies.

2. **Was the objective of the systems to improve any of the following? (Please select all that apply)**
   a. Safety (i.e., monitoring trespassing to address trespasser and suicide injuries and fatalities)
   b. Operation
   c. Maintenance
   d. Others ______
3. **Have you used or would you recommend any standards, guidance documents, or protocols when deploying vision-based or AI systems?**
   a. Yes or No
   b. If Yes –
      i. Please describe the standards, guidance documents, or protocols.
4. **Please identify and elaborate on the existence of any of the following items from the deployment.**
5. **Do you know of any peer agencies that have successfully used vision-based or AI systems that the project team could learn from?**
   a. Yes or No
   b. If Yes –
      i. Please provide the names and contact info of the peer agencies.

Summary of Findings

Nine transit agencies responded to the survey. The list of agencies is provided in Table 3-1.

Table 3-1. *Participating Transit Agencies*

No.	Name of Agency
1.	Washington Metrorail Safety Commission (WMSC), Washington DC
2.	Bay Area Rapid Transit (BART), San Francisco CA
3.	Southeastern Pennsylvania Transportation Authority (SEPTA), Philadelphia PA
4.	Los Angeles Los Angeles County Metropolitan Transportation Authority (METRO), Los Angeles CA
5.	New York City Transit Authority (NYCTA), New York City NY
6.	Port Authority of Allegheny County, Pittsburgh, PA
7.	Tri-County Metropolitan Transportation District of Oregon (TriMet), Portland OR
8.	Capital Metropolitan Transit Authority, Austin TX
9.	Massachusetts Department of Transportation, Boston MA

In total, 4 out of 9 respondents (44 percent) indicated their agency has deployed a vision-based system (see Figure 3-1). The four agencies are:

1. SEPTA
2. TriMet
3. Capital Metropolitan Transit Authority
4. Massachusetts Department of Transportation

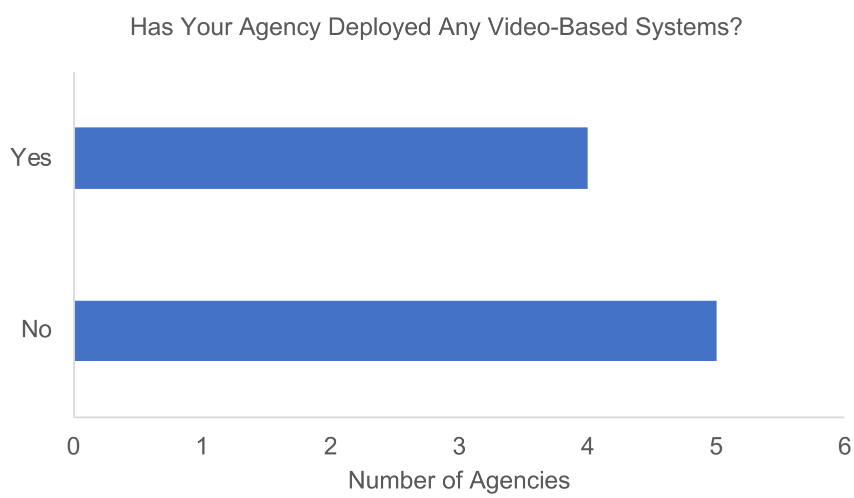


Figure 3-1 *Video-Based Systems Deployment*

When asked if the systems have video data analytics capabilities or AI and machine learning features, only one of the four agencies that have video-based systems answered yes (see Figures 3-2 and 3-3). TriMet is the only agency that specified their plan to deploy AI systems by October 2021.

A brief description of each of the four video-based systems, including the year and location of the deployment, is provided below:

SEPTA: SEPTA has on-vehicle video (forward- and inward-facing as well as inside coach cameras) and at station video systems. Their cameras have been in place since early 2000s on both vehicles and stations. The agency has cameras on all revenue vehicles, all subway stations, and on key city railroad stations.

TriMet: TriMet intends to implement video analytics software used for intrusion detection purposes and to collect quantitative safety data. The agency indicated their plan to fully implement the system by October 2021, which would be overlaid on all fixed cameras at light rail platforms.

Capital Metropolitan Transit Authority: Capital Metropolitan Transit Authority has adopted movement activated video systems on rail platforms since 2010.

Massachusetts Department of Transportation: The agency has live video monitoring, infrared video capture to assess subterranean water intrusion, and infrared video to support trespass prevention.

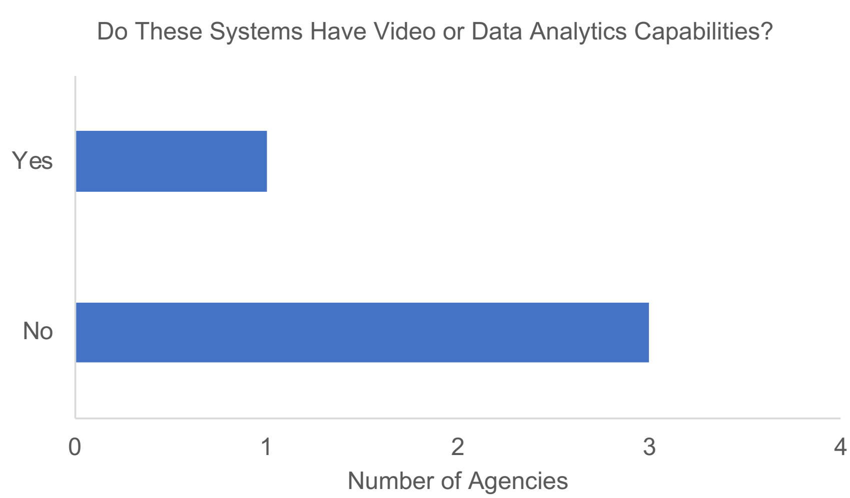


Figure 3-2 *Video or Data Analytics Capabilities*

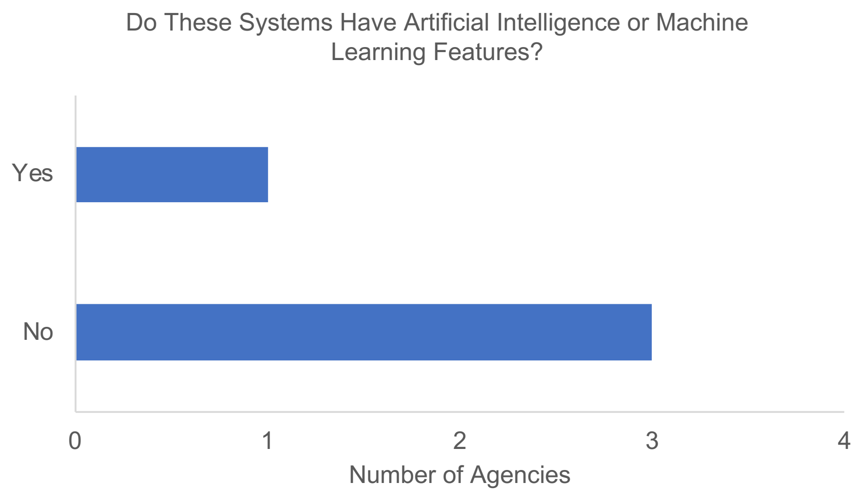


Figure 3-3 *Artificial Intelligence or Machine Learning Features*

Most of the agencies used the video-based systems for safety and operation reasons (Figure 3-4). Claims management and security were two other objectives highlighted by the respondents. The list of objectives selected by the agencies that responded to that question are given as:

- SEPTA
  - Safety (i.e., monitoring trespassing to address trespasser and suicide injuries and fatalities)
  - Operations
  - Other (Please describe): *Claims management*
- TriMet
  - Safety (i.e., monitoring trespassing to address trespasser and suicide injuries and fatalities)
  - Operations
  - Maintenance
  - Other (Please describe): *The software will also be used for investigative purposes.*
- Capital Metropolitan Transit Authority
  - Other (Please describe): *Security*

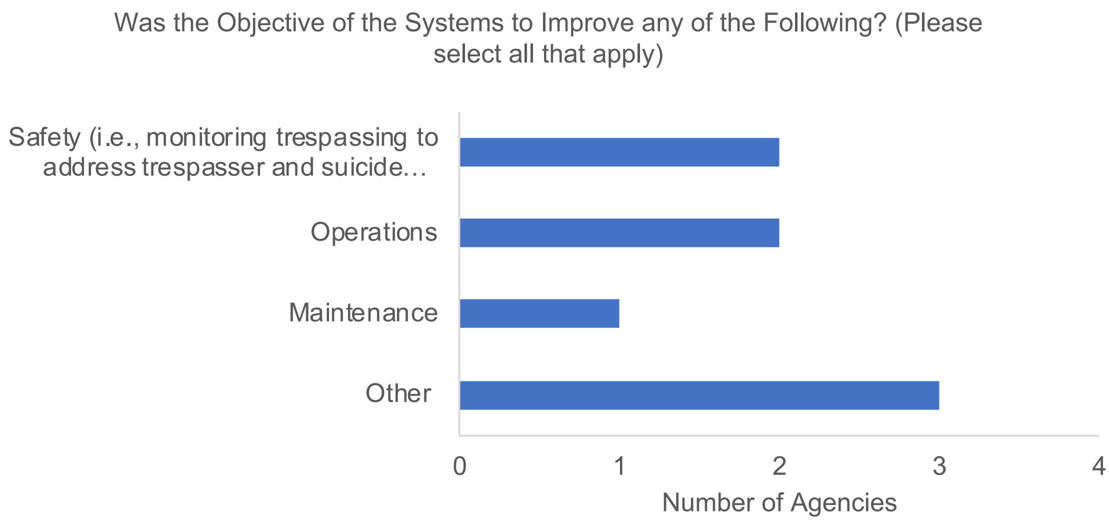


Figure 3-4 *Objective of the Systems*

None of the respondents have used standards, guidance documents, or protocols related to vision-based or AI systems. The agencies were then asked to rank from most important to least important four areas of standards: a) placement and specifications (e.g., field of view, operating temperature, resolution), b) the detection algorithm accuracy (e.g., false positive rate, false negative rate), c) data transfer, storage, processing, and communications between devices, and, d) visualization and alert output format (i.e., how the detection is delivered to the operations staff). These four areas comprise most of the considerations for a video-based system and are important for all deployments.

Most agencies ranked the area a) camera placement, and b) detection algorithm accuracy etc., higher than the data transfer and visualization areas. It was reported, however, that all areas are important, and therefore it was difficult to rank them. This question was merely asked to get an idea of the priority areas for future standards development. In other words, an area which was ranked lower, does not necessarily reflect an area that does not need attention, but rather a lower priority on standards development. Figure 3-5 shows the results of the ranking exercise.

Agency	Camera placement, specifications (e.g., field of view, operating temperature, resolution etc.)	Detection algorithm accuracy (e.g., false positive rate, false negative rate)	Data transfer, storage, processing, and communications between devices	Visualization and alert output format (i.e., how the detection is delivered to the operations staff)
1	1	2	3	4
2	1	2	4	3
3	1	3	2	4
4	2	1	4	3
5	3	2	1	4
6	3	1	2	4
7	2	1	3	4
8	1	4	2	3

Ranking legend: 1-most important, 4-least important

Figure 3-5 *Areas of Standards Ranking by Agencies*

Next, three of the survey respondents listed the benefits, drawbacks, and takeaways from deploying their video-based systems. Those benefits, drawbacks, and takeaways are synthetized next.

SEPTA

- Benefits:
  - The systems can help realize the significance in claims pay-outs and cases.
  - They can enhance accident/incident investigation capabilities and results.
- Drawbacks:
  - Lifecycle costs are needed to maintain equipment.
  - Lifecycle costs are needed to manage video and chain of custody requirements.
  - Equipment obsolescence and replacement every 8-10 years requires capital investment and planning.
  - The systems are very costly when large.
  - System reliability is an issue if equipment is not properly inspected and maintained.
- Takeaways:
  - Various systems must be compatible and properly interface with each other since both cameras and AI software are usually from the same vendors.

TriMet

- Benefits:
  - The video analytic software has the potential to collect information that would drastically reduce manpower required to complete the same task. It is an innovative solution for intrusion detection in our tunnels and on our bridges. It streamlines components of criminal investigations and reduces the likelihood of operator error.
- Drawbacks:
  - The hardware and software are very costly, require a large amount of personnel to coordinate implementation, and ongoing support and maintenance costs must be accounted for.
- Takeaways:
  - The full implementation of the technology is innovative and will benefit TriMet in ways that have not been fully realized.

Capital Metropolitan Transit Authority

- Benefits:
  - The systems allow viewing of platforms without deploying staff.
- Drawbacks:
  - They can be expensive and sometimes provide limited views.

Respondents that indicated they did not have video-based systems were asked if they would be interested in such systems (see Figure 3-6) and the reasons why they would be beneficial. The two agencies that responded positively to those questions highlighted their motives below.

Los Angeles METRO

- Trespass detection at grade crossings, in tunnels, and in platform areas
- Perimeter security & intrusion detection

New York City Transit Authority

- Video-based ("machine vision") systems can proactively capture and process data as well as communicate on a rate that cannot be done in any other manner.

The two agencies described funding, user interface, expertise in the field, and strong needs-based stakeholder group among their challenges. They also underlined their interest in using and benefitting from standards, guidance documents, or protocols when deploying video-based or AI systems.

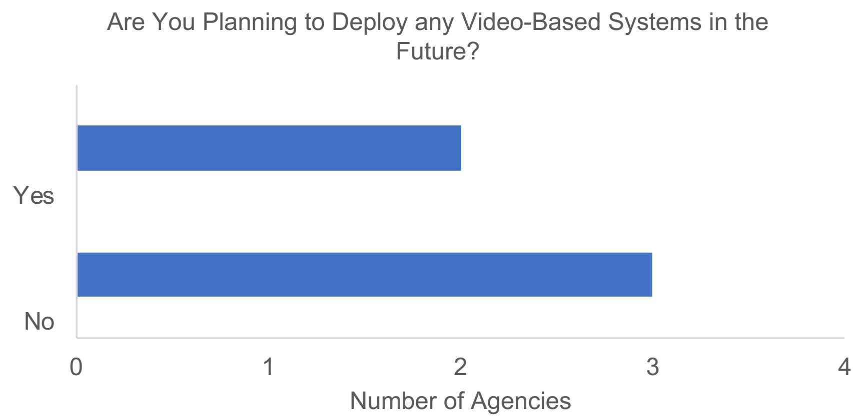


Figure 3-6 *Agencies Video-Based Systems Deployment in the Future*

Finally, respondents were asked to refer peer agencies/vendors/researchers that have used video-based or AI systems to the project team (Figure 3-7). New York City, Villanova University, and Mobileye and Bosch are three organizations that were mentioned to be working on video-based or AI systems. A respondent states that other firms (names not listed) are working on AI for security facial recognition and anomaly analytics. A few details given on the three listed organizations include the following:

- New York City Transit has extensively tested intrusion detection technologies in the subway.
- Villanova University is working on AI logic to be integrated with camera systems and drones.
- Mobileye and Bosch have algorithms interfacing with cameras for collision avoidance.

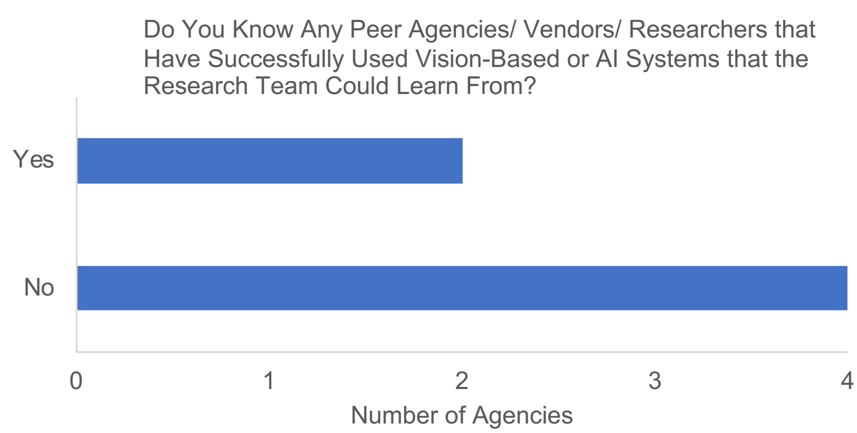


Figure 3-7 *Peer Agencies/ Vendors/ Researchers That Used Vision-Based or AI Systems*

Vendors

The project team has previous experience with vendors of such systems, based on work conducted for other related projects. The team identified three vendors of systems with AI capabilities that are currently available or indicated they are working on video analytics systems with AI for rail applications. The team arranged to speak with representatives of these vendors and interview them with a predefined set of questions for consistency. The questions used during the interviews are provided below.

Interview Questions

1. **Has your organization deployed any vision-based or AI systems?**
    a. Yes or No
    b. if Yes –
        i. Please describe the systems.
        ii. When did your organization deploy the systems?
        iii. Where did your organization deploy the systems (location, description of the setting)?
2. **Was the objective of the systems to improve any of the following? (Please select all that apply)**
    a. Safety
    b. Operation
    c. Maintenance
    d. Others
3. **Have you used or would you recommend any standards, guidance documents, or protocols when deploying vision-based or AI systems?**
    c. Yes or No
    d. if Yes –
        ii. Please describe the standards, guidance documents, or protocols.
4. **Please identify and elaborate on the existence of any of the following items from the deployment:**
    a. Success factors
    b. Takeaways
    c. Benefits and drawbacks
    d. Lessons learned

5. **Do you know of any peer vendors or transit agencies that have successfully used vision-based or AI systems that the project team could learn from?**
    a. Yes or No
    b. if Yes –
        i. Please provide the names and contact info of the peer vendors.

6. **In your opinion, are these AI or vision-based systems applicable to railroads?**
    a. Yes or No
    b. if Yes –
        i. Please describe how/where they are applicable/utilized in railroads.
        ii. In your opinion, what adjustments are needed for such applications?
    c. if No –
        i. Please describe why they cannot be utilized in railroads?

Summary of Findings

The four vendors interviewed have video-based systems used for traffic detection, which includes vehicles, pedestrians, and bicyclists. The systems have been deployed and are currently used on highways, arterials, intersections, rail tunnels, rail stations and rail crossings. Table 3-2 shows the summarized feedback received form the vendors on questions 1-4 and 6.

Table 3-2 *Summary of Feedback from Vendors*

Question	Vendor 1 Infrared system	Vendor 2 RGB system	Vendor 3 RGB system	Vendor 4 RGB system
Q1. Have the system been deployed?	The system has been deployed in traffic and rail environments.	The system has been deployed only in traffic environments.	The system has been deployed only in traffic environments.	The system has been deployed only in traffic environments. It is unique because it uses wide-angle cameras and captured intersection movements.
Q2. Objective of the deployments?	Primarily safety, and security. The system detects and alerts for trespassers on ROW or stopped vehicles/pedestrians. New system also for enhanced operations.	Primarily safety, and security. The system detects and alerts for stopped vehicles or pedestrians on roads/tunnels.	Primarily safety, and operations. The system detects and alerts for stopped vehicles or pedestrians on road and is used for signal activation.	Primarily operations and safety. System is used to detect vehicles, pedestrians/bicyclists and provides analytics platform.

Question	Vendor 1 Infrared system	Vendor 2 RGB system	Vendor 3 RGB system	Vendor 4 RGB system
Q3. Used or recommend standards/ protocols?	Only standards related to environmental hardness (IP) and communications	Only standards related to environmental hardness (IP) and communications	Only standards related to environmental hardness (IP) and communications	Only standards related to environmental hardness (IP) and communications
Q4. Identify/ elaborate on items from the deployment.	Successfully implemented in countries in the EU, collaboration with the agencies for site selection, learned from car traffic environment. Power and data access at remote locations is a challenge.	The deployed systems work well for traffic environment, a challenge is access to the site, power, and lighting conditions.	Systems used for automated detection and as vehicle detectors for traffic environment. Work well in most conditions, except inclement weather. Additional sensors can be used to offset this drawback.	System is successfully used in traffic environment in the US usually at intersection locations. Good lighting, camera location and data transfer is crucial.
Q6. Are these systems applicable to railroads?	Yes these systems have been deployed and can be enhanced in rail environment. AI solutions can help the industry by providing analytics and alerts about trespassing incidents fast and accurately.	Even though this vendor has not deployed in rail environment, they think these systems can be applied successfully and provide insights, increase safety.	Even though this vendor has not deployed in rail environment yet, they have plans to expand and think these systems can be successful in increasing awareness, and safety by providing alerts and further analytics.	These systems can be modified/customized for rail applications if the business case is made for the company. The detection is only a small part of the system. The rest of the system must be able to deliver alerts, analytics, etc.

Researchers

The project team was successful in speaking with four researchers with deep knowledge of the topic. Three worked at the University of South Florida and one works with the Rutgers Rail Program. The researchers have varying experience in the realm of video detection and machine vision and their research topics include industrial systems, military and defense, medical, and rail trespasser applications. The questions asked during the personal interviews are shown below and a summary of their input follows.

Interview Questions

1. **Have you worked on any vision-based or AI systems related projects?**
    a. Yes or No
    b. if Yes –
        i. Please describe the systems and projects.
        ii. When did you work on the projects?
        iii. Where did your research team deploy the systems (location, description of the setting)?

2. **Was the objective of the systems to improve any of the following? (Please select all that apply)**
   a. Safety
   b. Operation
   c. Maintenance
   d. Others
3. **Please identify and elaborate on the existence of any of the following items from your experience working on AI/vision-based projects:**
   a. success factors
   b. takeaways
   c. benefits and drawbacks
   d. lessons learned
4. **In your opinion, are these AI/vision-based systems applicable to railroads?**
   a. Yes or No
   b. if Yes –
      i. Please describe how/where they are applicable/utilized in railroads.
      ii. In your opinion, what adjustments are needed for such applications?
   c. if No –
      i. Please describe why they cannot be utilized in railroads?
5. **Have you identified or would you recommend any standards, guidance documents, or protocols based on your research?**
   a. Yes or No
   b. if Yes –
      i. Please describe the standards, guidance documents, or protocols.
6. **Do you know of any peer researchers/vendors/transit agencies that have successfully used vision-based or AI system that the research team could learn from?**
   a. Yes or No
   b. if Yes –
      i. Please provide the names and contact info of the peer agencies/vendors/researchers.

7. **Are you aware of any upcoming development or new systems related to vision-based and/or AI systems?**
    a. Yes or No
    b. if Yes –
        i. Please describe the upcoming development or new systems.

Summary of Findings

The researchers interviewed have a variety of backgrounds, and their expertise spans several topics on applications of machine vision, video detection and AI applications (e.g., medical image monitoring, defense, industrial applications, and trespasser monitoring). The researchers stated that based on their experience and the state of the practice, vision-based systems with AI are mature to be applied and deployed for trespasser detection.

The topic of object detection using video is mature and has been used successfully in many industries for decades. Currently, the low cost of components needed for such systems makes the application of these mature algorithms possible for various industries. The researchers state that an emerging technological advancement will be the increase in accuracy and application of analytics to help in visualization, dissemination, and real-time detection of trespassers on rail tracks. Table 3-3 provides the input received from the researchers interviewed on the questions presented in the previous section.

Table 3-3 *Summary of Feedback from Researchers*

Question	Researcher 1: Sudeep Sarkar, Ph.D.	Researcher 2: Dmitry B. Goldgof, Ph.D.	Researcher 3: Rangachar Kasturi, Ph.D.	Researcher 4: Asim F. Zaman, PE
Q1. Have you worked on any vision-based or AI systems related projects? If yes, please describe the systems and projects, the timeline and where did your research team deploy the systems (location, description of the setting)?	Have developed, customized and modified AI algorithms and systems with video detection and machine vision for industrial systems, military, and other applications. Work experience spans 15+ years in the field. Systems have been piloted and commercial products can be developed.	Experience with computer vision, medical vision lung cancer detection and diagnosis, predict outcome based on pictures, and non-medical domain applications. Have performed demonstration projects, both in post processing, and real time video processing for pain processing with hospitals, video cameras to detect ships on buoys, security systems and public transportation (buses).	Experience with computer vision, NASA projects and airports to improve vision with fog, related to person detection. Also used biometrics to detect person features. Research spans 35+years with different applications and projects. Worked on several different algorithms that were delivered as part of the project but not necessarily implemented in mass. Worked on NASA, NSA projects and collaboration with other researchers on medical imaging.	Worked with research team to develop rail trespasser detection system. System has been piloted and maintained at a few select sites and is being enhanced to include more features and improve accuracy. Worked in this field for a few years but highly focused on this topic.
Q2. Was the objective of the systems to improve safety, operations, maintenance, or others?	Objectives included automating processes and improved operations of industrial and medical applications.	Objectives included improving and creating automated processes for medical imaging and security.	All projects had the objective to improve safety or security and automated processes to improve operations.	To improve safety of railroads by automating trespasser detection and mitigation.
Q3. Identify and elaborate on the existence of success factors, takeaways, benefits/ drawbacks, and lessons learned from your experience working on AI/ vision-based projects:	There is always room for improvement, and applications usually need customization of existing algorithms which have gotten much better over the years. Expectations need to be considered form the beginning to establish successful outcomes.	This is a well-developed industry, and many products are available. It is important to collect data during the process to improve the algorithms, define PM from the beginning: define accuracy, FP rate, consider the background of the images, light conditions, and infrared applications.	Always compare with baseline library to evaluate effectiveness and establish methods in the beginning to improve the algorithms. Collect data during implementation and validation and know the hardware limitations (weather, light conditions).	The existing algorithms work well and perform relatively well in optimum conditions. The customization for each location aids in improving accuracy, but this is a balance between error rates.

[1] Dr. Sarkar webpage: https://www.usf.edu/engineering/cse/people/sarkar-sudeep.aspx
[2] Dr. Goldgof webpage: https://www.usf.edu/engineering/cse/people/goldgof-dmitry.aspx
[3] Dr. Kasturi webpage: https://www.usf.edu/engineering/cse/people/kasturi-rangachar.aspx
[4] Dr. Zaman webpage: https://www.linkedin.com/in/asim-francis-zaman-p-e-7112873b

Question	Researcher 1: Sudeep Sarkar, Ph.D.	Researcher 2: Dmitry B. Goldgof, Ph.D.	Researcher 3: Rangachar Kasturi, Ph.D.	Researcher 4: Asim F. Zaman, PE
Q4. In your opinion, are these AI/vision-based systems applicable to railroads?	Yes, this has been done in traffic applications, so it could be done for rail roads as well.	Yes, with customization of the scene, they can be applied to railroads.	Yes, they can be applicable if there is a well-lit, and stable view.	This is the focus of the work conducted under my research so yes, it can be applied to railroads.
Q5. Have you identified or would you recommend any standards, guidance documents, or protocols based on your research?	Standards always follow research so during development we don't follow standards unless we use an existing system.	For surveillance not aware, but for medical standards there are several that must be followed. Perhaps there are standards in the security area.	Specifically for imaging there are standards from collaborative groups, NIH, and NSA. Would recommend standards on camera placement, lighting levels etc.	Not followed any particular standards.
Q6. Do you know of any peer researchers, vendors, transit agencies that have successfully used vision-based or AI system that the research team could learn from?	Yes, provided peer researchers, some in this list. Also provided vendor name that provides camera systems.			
Q7. Are you aware of any upcoming development or new systems related to vision-based and/or AI systems?	The video detection of persons is a very well researched area and there is not much new development on algorithms. The applications are being expanded as less expensive hardware becomes available.	New developments are in applications of these systems, not necessarily the algorithms.	Person detection and recognition, working on high resolution data (as computing allows) and solving low light conditions. The YOLO algorithm is very popular because its fast and performs very well. New versions are being released as it improves.	Adding analytics on the system to provide a comprehensive system is the new development.

Section 4

Identified Needs for Standards and Subsequent Activities

Existing Standards and Protocols

The project team identified some of the most important standards, guidelines, and protocols from Section 2 that transit agencies can implement, modify, and adapt to monitor trespassing on railroad properties. The list of those standards, guidelines, and protocols are grouped into categories as in Section 2. Transit standards and standards in other industries that are pertinent to transit are selected. The standards in other industries are grouped into subcategories, such as monitoring, data, and AI systems and algorithms. A synthesis of the important standards by categories is provided next.

Transit Safety Standards

- **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**: Provides selection guidelines for cameras in fixed and mobile systems on trains or other transit environment. The practice can ensure good quality images, recordings, and network systems are used within transit-related CCTV systems.
- **RIS-2712-RST Iss 1 On-Train Camera Monitoring Systems**: It elaborates on the use of modern camera systems for the purposes of recording, storing, and accessing video data from rolling stock. It contains guidance on methods to protect the camera systems and data storage from physical or cyber unauthorized access, and what the British Transport Police needs when using the recorded data as part of an investigation.

Standards in Other Industries Applicable to Transit Monitoring

- **ISO 19237: 2017 — Intelligent Transport Systems— Pedestrian detection and collision mitigation systems (PDCMS) — Performance requirements and test procedures**: It indicates the concept of operation, minimum functionality, system requirements, system interfaces, and test procedures for pedestrian detection and collision mitigation systems (PDCMS). It indicates recommended behaviors for PDCMS. PDCMS detect pedestrians in advance and alert the driver in case of danger. The systems also determine if the danger can be avoided.
- **ISO 17386: 2010 Transport information and control systems — Maneuvering Aids for Low-Speed Operation (MALSO) — Performance requirements and test procedures**: It covers minimum functionality requirements of the device, such as information on the presence of relevant obstacles within a defined short detection range.

- **IEC 62676-4: 1ED 2014 Video Surveillance Systems for Use in Security Applications – Part 4: Applications Guidelines**: It provides recommendations and requirements for the selection, planning, installation, commissioning, maintaining, and testing of video surveillance systems (VSS) comprising of image capture device(s), interconnection(s), and image handling device(s), for use in security applications.
- **ASTM D 8205: 2020 Standard Guide for Video Surveillance System**: It includes recommended video surveillance systems for protecting waste, currency, people, property, and assets.
- **AS/NZS IEC 62676.3: 2020 Video surveillance systems for use in security applications Analog and digital video interfaces**: It describes physical, electrical and software interface (non-IP) specifications of analogue and digital video interface in video surveillance systems (CCTV) applications. Video interfaces are used both for connection and transmission of surveillance video, audio, and control signals. Through video interfaces, video surveillance systems can be put together by connecting various components such as image capturing devices, image handling devices, etc. This standard ensures interoperability among various video surveillance components.
- **CEI EN 50132-7: 2014 Alarm Systems – CCTV Surveillance Systems for Use in Security Applications – Part 7: Application Guidelines**: It gives recommendations and requirements for the selection, planning, installation, commissioning, maintaining, and testing of CCTV systems comprising of image capture device(s), interconnection(s), and image handling device(s), for use in security applications.

Data

- **SAE J1698 – Event Data Recorder (EDR)**: It offers common data output formats and definitions for a variety of data elements that may be useful for analyzing vehicle crashes and crash-like events that meet specified trigger criteria.
- **IEEE P7002 – IEEE Draft Standard for Data Privacy Process**: It describes requirements for a systems/software engineering process for considering privacy when dealing with personal data. It enables compliance testing with specific privacy practices by using specific procedures, diagrams, and checklists. The standard also provides a use case and data model using products, systems, processes, and applications that involve personal information.

AI Systems and Algorithms

- **AIR6994 Use Case AIR**: It summarizes AI technologies, architecture, validation approaches, and safety concerns for each use case.

- **IEC 62243:2012 Artificial Intelligence Exchange and Service Tie to All Test Environments (AI-ESTATE)**: It covers formal specifications for supporting system diagnosis. These specifications support the exchange and processing of diagnostic information and the control of diagnostic processes.
- **ISO/IEC PRF TR 24029-1 Artificial Intelligence (AI) -- Assessment of the robustness of neural networks**: This standard summarizes approaches available to evaluate risks related to the robustness of AI systems, especially risks related to neural networks.
- **ISO/IEC TR 24028:2020 Information technology -- Artificial intelligence -- Overview of trustworthiness in artificial intelligence**: This standard summarizes subjects related to trustworthiness in AI systems, including approaches to establish trust in AI systems through transparency, explainability, controllability, etc. The subjects also include engineering pitfalls; typical associated threats and risks to AI systems; possible mitigation techniques and methods; and approaches to evaluate and achieve availability, resiliency, reliability, accuracy, safety, security, and privacy of AI systems.
- **IEEE P3333.1.3 - Standard for the Deep Learning-Based Assessment of Visual Experience Based on Human Factors**: This standard describes deep learning-based metrics of content analysis and quality of experience (QoE) assessment for visual contents, which is an extension of Standard for the Quality of Experience (QoE) and Visual-Comfort Assessments of Three-Dimensional (3D) Contents Based on Psychophysical Studies (IEEE STD 3333.1.1)) and Standard for the Perceptual Quality Assessment of Three Dimensional (3D) and Ultra High Definition (UHD) Contents (IEEE 3333.1.2).
- ***ISO/IEC WD 22989: Artificial Intelligence Concepts and Terminology**: It will cover AI concepts and Terminology.
- ***ISO/IEC WD 23053: Framework for Artificial Intelligence (AI) Systems Using Machine Learning (ML)**: It will provide a framework for AI systems using machine learning (ML).
- ***ISO/IEC NP TR 24027: Information technology — Artificial Intelligence (AI) — Bias in AI systems and AI aided decision making**: It will cover bias in AI systems and AI-based decision making.
- ***ISO/IEC NP TR 24030: Information technology — Artificial Intelligence (AI) — Use cases**: It will cover IT and AI-related use cases.
- **IEEE P2671 – Standard for General Requirements of Online Detection Based on Machine Vision in Intelligent Manufacturing**: It uses machine vision to provide requirements for data format, data transmission processes, definition of application scenarios, and performance metrics for evaluating the effect of online detection deployment.

- **IEEE P2840 - Standard for Responsible AI Licensing**: The standard describes specifications for the factors that shall be considered in the development of a responsible artificial intelligence (AI) license.
- **IEEE P2863 – Recommended Practice for Organizational Governance of Artificial Intelligence**: It defines governance criteria, including safety, transparency, accountability, responsibility, bias, and process steps for effective implementation, performance auditing, training and compliance in the development or use of artificial intelligence within organizations.

***Under Development**

Gaps in Existing State of Practice and Standards

Standards exist that cover many areas of vision-based and AI systems separately. Selection of camera type for monitoring, detection and video surveillance systems, data output formats and privacy, as well as robustness, trustworthiness, and licensing of AI algorithms are examples of areas with available standards. One area that lacks specific standards is the area that describes the behavior of AI systems, especially vision-based AI systems. Understanding how the AI systems work to detect trespasses on railroad properties will be beneficial for their faster adoption in transit industries. Among the identified standards, the ISO/IEC NP TR 24027 standard, published in November 2021, covers parts of AI decision-making, which is the steps taken in the algorithm to make decisions after a certain input is detected. The standard covers bias in AI-aided decision making. However, standards that comprehensively elaborate on the vision-based AI system decision-making process will be an asset to transit agencies. For example, standards describing AI decision making related to design, data collection, training, learning, testing, and evaluation of vision-based systems could be useful.

Additionally, many of the identified standards have important facets that can be gathered to make a complete and beneficial implementation guide of vision-based AI systems for monitoring trespassing on railroad properties. Up to now, a complete guide is not available to transit agencies. In the future, developing a comprehensive guide could be a useful tool that will benefit railroad agencies in acquiring systems to monitor trespassers on their properties. Table 4-1 outlines a summary of existing standards in both the transit industry and related industries, as well as the current gaps or needs for those standards, separated by the four categories reviewed by the project team.

Table 4-1 *Summary of Existing Standards and Gaps for Transit Industry*

Category	Existing Standards in Transit Industry	Existing Standards in Related Industries	Gaps/Needs
Definitions, key terms, concepts, terminology	• N/A	• ISO/IEC WD 22989* • ISO/IEC WD 23053*	Gaps for transit industry
Monitoring, sensing, object and event detection and response	• APTA IT-CCTV-RP-001-11 • RIS-2712-RST Iss 1	• ISO 19237:2017 • ISO 17386:2010 • IEC 62676-4: 1ED 2014 • ASTM D 8205: 2020 • AS/NZS IEC 62676.3:2020 • CEI EN 50132-7: 2014 • ISO/IEC NP TR 24027* • IEEE P2671	Need more standards to cover specific use case of trespassers
Data and communication	• N/A	• SAE J1698 • IEEE P7002	Gaps for transit industry
AI systems or algorithms	• N/A	• AIR6994 Use Case AIR • IEC 62243:2012 • ISO/IEC PRF TR 24029-1 • ISO/IEC TR 24028:2020 • IEEE P3333.1.3 • ISO/IEC NP TR 24030* • IEEE P2840 • IEEE P2863	Gaps for transit industry

*Note: * In Development*

Section 5

Findings and Recommendations

Trespassing along railroad ROW is the leading cause of rail-related fatalities in the U.S. Several federal datasets show the extent of the issues. For example, based on FRA and NTD data, several hundreds of trespassing fatalities occur each year and often about 18 percent of all transit rail fatalities involve trespassers. Attempts to reduce trespassing on rail properties are essential for railroad safety and reduction of fatalities. The aim of this project was to understand how vision-based AI systems can be used to monitor trespassers on railroad properties for the improvement of transit safety, to collect best practices and to investigate if any standards are used in their deployment. The project team conducted an online literature review for standards related to vision-based systems, a survey of transit agencies belonging to the FTA CUTR Standards Development Group, and interviews with vendors and researchers to uncover information on vision-based AI applications. This process served to collect recommendations on best practices, use of existing relevant standards, and needs for standards development to assist with the use of AI with vision-based systems. The findings from the project are synthetized in the following sections.

Findings

Vision-based systems with AI applications, useful for detecting, identifying, and categorizing various types of events along rail tracks, were separated into three groups: 1) agency deployments, 2) vendor products, and 3) research studies. The team researched available research and case studies to establish the current state of practice.

Examples of AI applications by transit agencies include:

- Vision-based trespasser detection system with AI and video analytics by TriMET, Oregon
- Intruder detection in Melbourne, Australia
- The collaboration between Nokia and Odakyu Electric Railway in Japan involving the use of a machine-learning based AI solution for detecting trespassing at rail crossings and identifying potential issues in real time

Examples of vendor products with vision-based AI frameworks comprise:

- Thermal (infrared) or RGB-based solutions that use machine learning-based AI frameworks to identify potential issues at railroad crossings
- Learning/vision-based solutions, which are tireless solutions, employing deep learning (DL) technology to automate incident detection and reduce false positive detections

Related research studies identified:

- The Mask R-CNN AI and video-based analytics approach by Rutgers University, which has been effectively used in analyzing big video data in railroad trespassing
- The research study conducted at North Carolina State University that considered the use of AI to detect pedestrian incidents in the railroad ROW
- Other research studies that explored the use of vision-based and AI systems in the railroad environment. Those studies either suggest the need for improvement in low lighting or some weather conditions, or the potential to apply AI frameworks like the CNN algorithm, a highly data intensive, but highly effective tool in detecting high-risk behavior with a high level of accuracy.

The input from the three groups of stakeholders (transit agencies, vendors, and researchers) regarding AI applications and the use of AI standards disclosed further details. From the transit agency survey, nine agencies responded to the survey and 44 percent of those agencies confirmed using vision-based systems. TriMet was the only agency in the process of deploying vision-based AI system with video analytics. Vision-based systems were mostly used for safety, operation, claims management, and security. Based on the survey findings, agencies are not currently using standards, guidance documents, or protocols related to vision-based AI systems. However, the four areas listed below were deemed important for standards development in the future, or implementation of existing standards in transit and related industries:

- **Camera placement and specifications** (e.g., field of view, operating temperature, camera resolution, minimum light conditions, camera height etc.): these standards would describe and guide deployers on how to select cameras and where to install them to achieve their desired goals.
- **Detection accuracy** (e.g., false positive rate, false negative rate, precision, recall, etc.): These standards would provide acceptable ranges of detection accuracy of the system under certain conditions. At this time, there are no standards for the transit industry and exact detection ranges will be difficult to establish or agree upon since the algorithms have great variability of accuracy and depend on many site-specific factors.
- **Data transfer, storage, processing, and communications between devices** (e.g., data format, transfer protocol, processing time, storage limit etc.): these standards would guide deployers on the data collected and transferred between site devices (camera, edge computer) and servers, cloud storage, or terminals/displays at the control center. Standards can also require certain computing processing capacity, as the large amount of data require higher processing power to provide real time results. There are existing standards that apply to similar data, storage, and communications

that can be used for this purpose. Agencies likely have their own data handling protocols or standards for existing systems (i.e., CCTV).

- **Visualization and output** (i.e., how the detection is reported or delivered to the operations staff): these standards would guide deployers on what to expect on the end user side, where the alert and/or reporting is delivered. Currently, each vendor offers their own visualization platform and can have different features. However, common and vendor agnostic guidance would benefit agencies that might change vendors after initial deployment.

During interviews, agency representatives stated that it was difficult to rank the four areas, as they are all very important in a deployment plan and considerations should be made by agencies planning to deploy them in the future. Especially the data transfer/storage/processing and visualization/output if not considered can limit deployments to a few cameras, due to limitations in data processing and storage.

Transit agency respondents stated that current and future benefits of using vision-based AI systems for monitoring trespassers include reduction of manpower or presence of staff at stations for surveillance purposes, innovative solution for intrusion detection, streamlining components of accident/incident/criminal investigations, reduction of the likelihood of operator error, and usefulness in claims cases and payout cases. On the other hand, lifecycle costs, capital funding, user interface, expertise in the field, and strong needs-based stakeholder group, present challenges and drawbacks when deploying and maintaining vision-based AI systems.

Best practices for the deployment of such systems include the use of well-established vendors and companies and working with the company to customize systems setup so that it provides accurate results. Agencies also suggested that even though not required, it is of great benefit in saving resources to use the same company for cameras and the AI and analytics suite. This will, at a minimum, streamline the process of solving challenges, which will undoubtedly arise. However, this might prove difficult, as many solutions exist, but not all offer the level of analytics that a transit agency can benefit from. Nonetheless, this can be added at a later point by working on post processing of data (video, images) to provide reports on a regular basis and not in real time.

Finally, a best practice for deployment is to establish the funds needed, goals, and evaluation protocols (via a pilot) to ensure adherence to budgets and schedules. Defining the requirements and needs from the onset of a deployment may lead to better outcomes in implementation and use of such systems.

Recommendations

Upon completion of interviews with vendors, agencies, and researchers, the team identified areas where standards or guidance documents could be developed, so that agencies interested in deployment of such systems can have a comprehensive direction in their use of vision-based AI systems for monitoring trespassing at railroads.

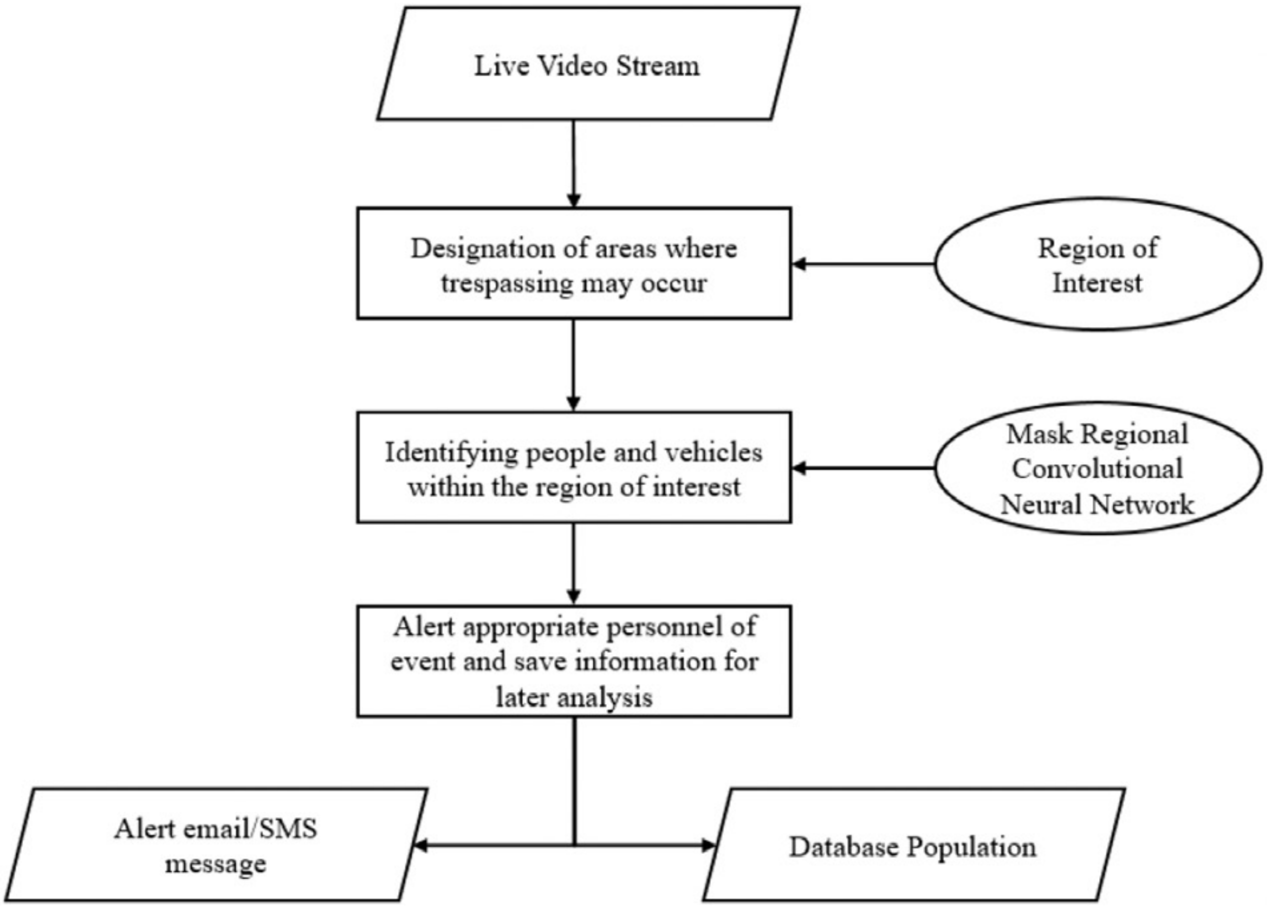
Several standards associated with vision-based AI systems are currently available, such as standards related to the selection of camera type for monitoring, detection, and video surveillance systems; data output formats; and privacy, robustness, trustworthiness, and licensing of AI systems.

The team recommends that the following be considered to aid in successful deployment of such systems in the future:

- **Development of standards or guidance documents expanding on the behavior of vision-based AI systems**. A standard document that can systematically cover the vision-based AI system decision-making process could serve transit agencies in the future. This can also be done by gathering important aspects from the identified standards in this report to produce a complete implementation guide of vision-based AI systems for monitoring trespassing on railroad properties.
- **Development of standards** covering the four aforementioned areas: **1) camera placement/specifications, 2) detection accuracy, 3) data collection and communications, and 4) visualization and output of detection results and alerts**.
- **Guidance on best practices for successful implementation** of such systems that includes system framework and architecture, recommendations on items to include in requisition proposals (e.g., maintenance (warranty) support, operations support, phased implementation).
- **Pilot deployment of vision-based systems with AI** and publication of results to benefit the rail transit industry.
- **Engagement of successful and proven vendors** for system requisition, to increase the success rate.

These recommendations will increase the use and acceptance of such systems, which are not widely used by the transit industry, but can be implemented quickly, especially when an agency has existing closed-circuit television (CCTV) systems in place for security and monitoring. Applying artificial intelligence algorithms on existing video feeds can enhance trespass monitoring operations and increase safety at the specific locations with camera coverage.

Appendix A AI Framework for Railroad Trespass Detection



Source: Zaman et al., 2019

Figure A-1 *General AI Framework for Detecting Trespassing at Railroads*

Appendix B

AI and Vision-Based Systems Related Standards and Protocols Found in Literature

Table B-1 *Standards Related to Monitoring, Communication, and Response in the Transit Industry*

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
APTA	**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	Recommended Practice	06/01/2011	Provides selection guidelines for cameras in fixed and mobile systems on trains or other transit environment. The practice can ensure good quality images, recordings, and network systems are used within transit-related CCTV systems.
APTA	**APTA RT-OP–RP-024-19** Crash and Fire Protected Inward and Outward Facing Audio and Image Recorders in Rail Transit Operating Compartments	Recommended Practice	04/12/2019	Summarizes minimum requirements for selection, installation, operating and maintenance requirements for crash and fire protected inward and outward facing audio and image recorders in all rail transit vehicle operating compartments. Enables collection of important data for investigating accidents and managing the safe operations of trains.
APTA	**APTA BTS-BRT-RP-005-10** Implementing BRT Intelligent Transportation Systems	Recommended Practice	10/01/2010	Guides transit agencies by documenting types of ITS that can be considered for BRT and underlines best practices and examples. Covers the integration of the ITS elements into the building, operating, and maintaining of BRT services and infrastructure. This recommended practice can be adapted for rail systems and for monitoring trespassing using AI.
APTA	**APTA RT-VIM-S-026-12** Rail Transit Vehicle Passenger Emergency Systems	Standard	December 2012	Provides recommended practices, guidelines, and requirements for various passenger emergency systems for new rail transit vehicles.

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
IEEE	**IEEE 1473** An open-source communications protocol for railway vehicles	Protocol	Nov.-Dec./2003	Includes two variants, the type T and L standards that integrate safe default behavior into message responses. Improves safety and reliability of rail systems. For further reliability and safety, Type T provides for freshness monitoring, while type L offers heartbeat monitoring to ensure that network data is valid. Freshness monitoring involves timestamping of the data. In contrast, heartbeat monitoring involves using the system clock to ensure that essential functions continue to run. The system uses Manchester encoding and cyclic redundancy checking on the packets to ensure their integrity.
IEEE	**IEEE 1474.4-2011** IEEE Recommended Practice for Functional Testing of a Communications-Based Train Control (CBTC) System	Recommended Practice	2011-09-16	Summarizes recommended methods for functional testing of a communications-based train control (CBTC) system, based on the CBTC system design and functional allocations.
RSSB	**RIS-2712-RST Iss 1** On-Train Camera Monitoring Systems	Guidance	07/03/2020	Elaborates on the use of modern camera systems for the purposes of recording, storing, and accessing video data from rolling stock. It contains guidance on methods to protect the camera systems and data storage from physical or cyber unauthorized access, and what the British Transport Police needs when using the recorded data as part of an investigation.

Table B-2 *Definitions, Key Terms, Concepts, Terminology for Relevant Standards*

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
SAE	**SAE J2396_201705** Definitions and Experimental Measures Related to the Specification of Driver Visual Behavior Using Video Based Techniques	Recommended Practice Definitions/ Concepts/ Terminology	2017-05-26	For consistency, it includes definitions of key terms in evaluating video-based driver eye glance behavior and data. Can also assist when assessing the capability of automated sensors (eye trackers) and automated reduction (computer vision).

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
SAE	**SAE J3088** Active Safety System Sensors	Standard Definitions/ Concepts/ Terminology	2017-11-30	Defines the functionality and performance of active safety sensors.

Table B-3 *Standards Related to Monitoring, Sensing, Object and Event Detection and Response (Safety) (Other Fields)*

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
ISO	**ISO 19237:2017** Intelligent Transport Systems— Pedestrian detection and collision mitigation systems (PDCMS) — Performance requirements and test procedures	International Standard Detection/ Sensing/ Response Safety	2017-12	Indicates the concept of operation, minimum functionality, system requirements, system interfaces, and test procedures for Pedestrian Detection and Collision Mitigation Systems (PDCMS). Indicates recommended behaviors for PDCMS. PDCMS detect pedestrians in advance and alert the driver in case of danger. The systems also determine if the danger can be avoided.
ISO	**ISO 22839:2013** Intelligent Transport Systems— Forward vehicle collision mitigation systems —Operation, performance, and verification requirements	International Standard Detection/ Sensing/ Response Safety	2013-06	Describes the concept of operation, minimum functionality, system requirements, system interfaces, and test methods for Forward Vehicle Collision Mitigation Systems (FVCMS). Indicates recommended behaviors for FVCMS. FVCMS detect hazards in advance and alert the driver. The systems also help determine if the hazard can be avoided.
SAE	**SAE J3116_201706** Active Safety Pedestrian Test Mannequin	Recommendation Detection/ Sensing/ Response Safety	2017-06-01	Helps develop standard specifications/ requirements for pedestrian test mannequins (1 adult and 1 child) that are representative of real pedestrians to the sensors used in Pedestrian Detection systems and can be used for performance assessment of such in-vehicle systems (including warning and/or braking) in real world test scenarios/conditions.

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
SAE	**J3155** Camera Monitor Systems Test Protocols and Performance Requirements	Recommended Practice Monitoring	2017-09-13	Highlights test protocols with performance requirements for Camera Monitor Systems to replace existing statutorily required inside and outside rear-view mirrors for US market road vehicles.
SAE	**J3157_201902** Active Safety Bicyclist Test Targets Recommendation	Recommendation Safety (Object and Event Detection and Response)	2019-02-06	Helps develop standard specifications/requirements for bicyclist test mannequins (one adult and one child) that are representative of real bicyclists to the sensors used in Bicyclist Detection systems and can be used for performance assessment of such in-vehicle systems (including warning and/or braking) in real world test scenarios/conditions. Provides the recommended bicyclist mannequin characteristics for vision, Lidar, and/or 76 to 78 GHz radar-based Bicyclist Pre-Collision systems.
NIST	**NIST NISTIR 6910** 4D/RCS Version 2.0: A Reference Model Architecture for Unmanned Vehicle Systems	Standard Detection/Sensing/Response	2002-08	Offers a reference model for military unmanned vehicles on identifying and organizing software components. Offers well defined and highly coordinated sensory processing, world modeling, knowledge management, cost/benefit analysis, behavior generation, and messaging functions, as well as the associated interfaces.
ISO	**ISO/DIS 20035** Intelligent Transport Systems—Cooperative adaptive cruise control (CACC)—Operation, performance, and verification requirements	Standard Detection/Sensing/Response	2019-01	Covers two types of Cooperative Adaptive Cruise Control (CACC): V2V, and I2V. Both kinds of CACC system require active sensing using for example radar, lidar, or camera systems.
SAE	**SAE J2980_201804** Considerations for ISO 26262 Automotive Safety Integrity Levels (ASIL) Hazard Classification	Recommended Practice Safety	2018-04-28	Includes method and example results for determining the Automotive Safety Integrity Level (ASIL) for automotive motion control electrical and electronic (E/E) systems. Restricted to collision-related hazards associated with motion control systems.

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
ISO	**ISO 22840:2010** Intelligent Transport Systems —Devices to aid reverse maneuvers — Extended-range backing aid (ERBA) systems	Standard Detection/ Sensing/ Response	2010-04	Summarizes backing aid functionality over an extended area located behind vehicle using sensors for detection and ranging to inform the driver about the distance to obstacles.
ISO	**ISO 17386:2010** Transport information and control systems — Manoeuvring Aids for Low-Speed Operation (MALSO) — Performance requirements and test procedures	Standard Detection/ Sensing/ Response	2010-03	Covers minimum functionality requirements of the device, such as information on the presence of relevant obstacles within a defined short detection range.
SAE	**SAE J2945/X** Dedicated Short Range Communication (DSRC) Systems	Standard Safety Response	2017-12-07	Offers information exchange between a host vehicle and another DSRC enabled device, a device worn by or otherwise attached to a traveler, a roadside device, or a management center, to address safety, mobility, and environmental system needs.
IEC	**IEC 62676-2-2 : 1ED 2013** Video Surveillance Systems for Use in Security Applications - Part 2-2: Video Transmission Protocols – IP Interoperability Implementation Based on HTTP and Rest Services	Protocols Monitoring	11-20-2013	Describes the video transmission protocols based on HTTP and rest services.
IEC	**IEC 62676-4 : 1ED 2014** Video Surveillance Systems for Use in Security Applications – Part 4: Applications Guidelines	Standard Monitoring	05-06-2014	Provides recommendations and requirements for the selection, planning, installation, commissioning, maintaining, and testing video surveillance systems (VSS) comprising of image capture device(s), interconnection(s), and image handling device(s), for use in security applications.

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
ASTM	**ASTM D 8205 : 2020** Standard Guide for Video Surveillance System	Guide Monitoring	02-01-2020	Includes recommended video surveillance system for protecting waste, currency, people, property, and assets.
Standards Australia	**AS/NZS IEC 62676.3:2020** Video surveillance systems for use in security applications Analog and digital video interfaces	Standard Monitoring	04-24-2020	Describes physical, electrical and software interface (non-IP) specifications of analogue and digital video interface in video surveillance systems (CCTV) applications. Video interfaces are used both for connection and transmission of surveillance video, audio, and control signals. Through video interfaces, video surveillance systems can be put together by connection various components such as image capturing devices, image handling devices, etc. This Standard ensures interoperability among various video surveillance components.
Standards Australia	**AS/NZS 62676.5:2020** Video surveillance systems for use in security applications Data specifications and image quality performance for camera devices (IEC 62676-5:2018, MOD)	Standard Monitoring	04-24-2020	Used in Australia and New Zealand. Covers requirements for description of video surveillance camera specification items and measurement methods of video surveillance camera specification items.
Standards Australia	**AS/NZS 62676.2.1:2020** Video surveillance systems for use in security applications Video transmission protocols - General requirements (IEC 62676-2-1:2013, MOD)	Standard Monitoring	04-24-2020	Used in Australia and New Zealand, introduces an IP network interface for devices in surveillance applications. It specifies a network protocol for the full interoperability of video devices.
Danish Standards	**DS/EN IEC 62676-2-31:2019** Video surveillance systems for use in security applications – Part 2-31: Live streaming and control based on web services	Standard Monitoring	09-10-2019	Defines procedures for communication between network video clients and video transmitter devices.

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
Standards Australia	**AS/NZS 62676.1.2:2020** Video surveillance systems for use in security applications System requirements - Performance requirements for video transmission (IEC 62676-1-2:2013, MOD)	Standard Monitoring	04-24-2020	Used in Australia and New Zealand, summarizes general requirements on video transmission on performance, security, and conformance to basic IP connectivity, based on available, well-known, international standards.
Comitato Elettrotecnico Italiano	**CEI EN 50132-7: 2014** Alarm Systems – CCTV Surveillance Systems for Use in Security Applications – Part 7: Application Guidelines	Standard Monitoring	01-01-2014	Provides recommendations and requirements for the selection, planning, installation, commissioning, maintaining, and testing of CCTV systems comprising of image capture device(s), interconnection(s), and image handling device(s), for use in security applications.
British Standards Institution	**BS EN IEC 62676-6** Video surveillance systems for use in security applications. Part 6. Video content analytics. Performance testing and grading	Draft Standard Monitoring	07-16-2019	Specifies the functions, performance, interfaces, environmental adaptability, test methods, performance evaluation and grading rules of real-time intelligent video analysis in surveillance systems.
Netherlands Standards	**NEN EN 50132-4-1: 2001** Alarm Systems – CCTV Surveillance Systems – Part 4-1 Black and White Monitors	Standard Monitoring	01-12-2013	Specifies the minimum requirements for the specification and testing of black and white video monitors used in 625-line CCIR standard closed-circuit television (CCTV) surveillance systems for security applications.

Table B-4. *Data Related Standards Relevant to AI*

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
SAE	**J3197_202004** Automated Driving System Data Logger	Recommended Practice Data	2020-04-11	Provides common data output formats and definitions for a variety of data elements useful for assessing automated driving system (ADS) during an event that meets the trigger threshold criteria specified. It aims to enable the use of data from sensors such as camera(s), LiDAR(s) etc. in the absence of a human driver.
SAE	**SAE J1698** Event Data Recorder (EDR)	Recommended Practice Data	2017-03-17	Offers common data output formats and definitions for a variety of data elements that may be useful for analyzing vehicle crash and crash-like events that meet specified trigger criteria.
IEEE	**IEEE P7002** IEEE Draft Standard for Data Privacy Process	Draft Standard Data	2016-12-07	Describes requirements for a systems/software engineering process for considering privacy when dealing with personal data. It enables compliance test with specific privacy practices by using specific procedures, diagrams, and checklists. Provides a use case and data model using products, systems, processes, and applications that involve personal information.

Table B-5. *AI Systems/Algorithms*

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
SAE	**AIR6994** Use Case AIR	Standard AI Systems	2021-02-01	Summarizes AI technologies, architecture, validation approach, and safety concerns for each use case.
IEC	**IEC 62243:2012** Artificial Intelligence Exchange and Service Tie to All Test Environments (AI-ESTATE)	Standard AI Systems	21-Jun-2012	Covers formal specifications for supporting system diagnosis. These specifications support the exchange and processing of diagnostic information and the control of diagnostic processes.
ISO	**ISO/IEC PRF TR 24029-1** Artificial Intelligence (AI) -- Assessment of the robustness of neural networks	Standard AI Systems	1:2021	Summarizes approaches available to evaluate risks related to the robustness of AI systems, especially risks related to neural networks.

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
ISO	**ISO/IEC TR 24028:2020** Information technology -- Artificial intelligence -- Overview of trustworthiness in artificial intelligence	Standard AI Systems	27-May-2020	Summarizes subjects related to trustworthiness in AI systems, including approaches to establish trust in AI systems through transparency, explainability, controllability, etc. The subjects also include engineering pitfalls; typical associated threats and risks to AI systems; possible mitigation techniques and methods; approaches to evaluate and achieve availability, resiliency, reliability, accuracy, safety, security, and privacy of AI systems.
IEEE	**IEEE P2817** Guide for Verification of Autonomous Systems	Guide AI Systems	07 February 2020	Helps in setting up a customized process for verification of an autonomous system based on available resources. Covers best practices across all levels of abstraction within a given system and summarizes a conceptual model that assists in the development of new verification processes for autonomous systems and provides both integration guidance for developing a verification process and techniques, methodologies, and tool types supporting verification process development.
IEEE	**IEEE P3333.1.3 - 2022** Standard for the Deep Learning-Based Assessment of Visual Experience Based on Human Factors	Standard AI Systems	2017-09-28	Describes deep learning-based metrics of content analysis and quality of experience (QoE) assessment for visual contents, which is an extension of Standard for the Quality of Experience (QoE) and Visual-Comfort Assessments of Three-Dimensional (3D) Contents Based on Psychophysical Studies (IEEE STD 3333.1.1)) and Standard for the Perceptual Quality Assessment of Three Dimensional (3D) and Ultra High Definition (UHD) Contents (IEEE 3333.1.2).
ISO/IEC	**ISO/IEC WD 22989** Artificial Intelligence Concepts and Terminology	AI Systems	Under Development	Will cover AI concepts and Terminology.
ISO/IEC	**ISO/IEC WD 23053** Framework for Artificial Intelligence (AI) Systems Using Machine Learning (ML)	AI Systems	Under Development	Will provide framework for AI Systems Using Machine Learning (ML).

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
ISO/IEC	**ISO/IEC NP TR 24027** Information technology — Artificial Intelligence (AI) — Bias in AI systems and AI aided decision making	AI Systems	Under Development	Will cover bias in AI systems and AI based decision-making.
ISO/IEC	**ISO/IEC NP TR 24030** Information technology — Artificial Intelligence (AI) — Use cases	AI Systems	Under Development 2021-04	Will cover IT and AI related use cases.
IEEE	**IEEE P2247.1** Standard for the Classification of Adaptive Instructional Systems	Standard AI Systems	2018-06-14	Describes and categorizes the elements, functionality, and parameters of adaptive instructional systems (AIS). It also provides requirements and guidance for the use and measurement of these parameters.
IEEE	**IEEE P2247.2** Interoperability Standards for Adaptive Instructional Systems (AISs)	Standard AI Systems	2019-03-21	Describes interactions and exchanges among the components of adaptive instructional systems (AISs). It also describes the data, data structures, and parameters used in these interactions and exchanges. In addition, the standard provides requirements and guidance for the use and measurement of the data, data structures, and parameters.
IEEE	**IEEE P2247.3** Recommended Practices for Evaluation of Adaptive Instructional Systems	Recommended Practice AI Systems	2019-03-21	Describes and categorizes methods for assessing adaptive instructional systems (AIS). This recommended practice also provides guidance for the use of these methods. It includes principles of ethically aligned design for the use of artificial intelligence (AI) in AIS.
IEEE	**IEEE P2247.4** Recommended Practice for Ethically Aligned Design of Artificial Intelligence (AI) in Adaptive Instructional Systems	Recommended Practice AI Systems	2020-09-24	Summarizes ethical matters and recommends best practices in the design of artificial intelligence as used by adaptive instructional systems.

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
IEEE	**IEEE 2660.1-2020** Recommended Practice for Industrial Agents: Integration of Software Agents and Low-Level Automation Functions	Recommended Practice AI Systems	2021-01-29	Describes best practices to solve the interface problem when integrating intelligent software agents with low-level automation devices in the context of cyber-physical systems. Provides a method to select the best interfacing practice for a given application scenario specified by the user from a library of available interfacing templates and technologies to improve reuse, consistency, and transparency in the integration of industrial agents and low-level control functions.
IEEE	**IEEE P2671** Standard for General Requirements of Online Detection Based on Machine Vision in Intelligent Manufacturing	AI Standard AI Systems	2017-12-06	Uses machine vision to provide requirements for data format, data transmission processes, definition of application scenarios and performance metrics for evaluating the effect of online detection deployment.
IEEE	**IEEE P2830** Draft Standard for Technical Framework and Requirements of Trusted Execution Environment based Shared Machine Learning	AI Standard AI Systems	2020-05-15	Provides a framework and architectures for machine learning in which a model is trained using encrypted data that has been aggregated from multiple sources and is processed by a third-party trusted execution environment. Describes functional components, workflows, security requirements, technical requirements, and protocols.
IEEE	**IEEE P2840** Standard for Responsible AI Licensing	AI Standard AI Systems	2019-09-05	Describes specifications for the factors that shall be considered in the development of a Responsible Artificial Intelligence (AI) license.
IEEE	**IEEE P2863** Recommended Practice for Organizational Governance of Artificial Intelligence	Recommended Practice AI Systems	2020-02-13	Defines governance criteria, including safety, transparency, accountability, responsibility bias, and process steps for effective implementation, performance auditing, training and compliance in the development or use of artificial intelligence within organizations.
IEEE	**IEEE P2894** Guide for an Architectural Framework for Explainable Artificial Intelligence	Guide AI Systems	2020-06-03	Specifies an architectural framework and application guidelines that enables the adoption of explainable artificial intelligence (XAI), including: 1) description and definition of explainable AI, 2) the categorizes of explainable AI techniques; 3) the application scenarios for which explainable AI techniques are needed, 4) performance evaluations of XAI in real application systems.

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
IEEE	**IEEE P7000** Draft Model Process for Addressing Ethical Concerns During System Design	Model Process AI Systems	2016-06-30	Provides processes to include and evaluate traceability of human ethical values during concept exploration, development, and system design.
IEEE	**IEEE P7001** Draft Standard for Transparency of Autonomous Systems	Standard AI Systems	2016-12-07	Depicts measurable and testable levels of transparency to evaluate autonomous systems and their levels of compliance.
IEEE	**IEEE P7003** Algorithmic Bias Considerations	Standard AI Systems	2017-02-17	Summarizes specific methods to assist users certify how they worked to address and eliminate issues of negative bias in the creation of their algorithms, including 1) the usage of overly subjective or uniformed data sets or information known to be inconsistent with legislation protected groups (i.e., race, gender, sexuality, etc.); 2) bias against groups not necessarily protected explicitly by legislation, but otherwise diminishing stakeholder or user well-being, 3) application boundaries bias creating unintended consequences arising from out-of-bound application of algorithms; 4) bias due to incorrect interpretation of systems outputs by users (e.g. correlation vs. causation)
IEEE	**IEEE P7008** Standard for Ethically Driven Nudging for Robotic, Intelligent and Autonomous Systems	Standard AI Systems	2017-06-15	"Nudges" as exhibited by robotic, intelligent, or autonomous systems are defined as overt or hidden suggestions or manipulations designed to influence the behavior or emotions of a user. Describes typical nudges (currently in use or that could be created). It contains concepts, functions, and benefits necessary to establish and ensure ethically driven methodologies for the design of the robotic, intelligent, and autonomous systems.

Standards Development Organization	Document Title/Number/Link	Standard Type	Publication Date	Summary
IEEE	**IEEE P7009** Standard for Fail-Safe Design of Autonomous and Semi-Autonomous Systems	Standard AI Systems	2017-06-15	Creates a practical, technical baseline of specific methodologies and tools for the development, implementation, and use of effective fail-safe mechanisms in autonomous and semi-autonomous systems. Summarizes procedures for measuring, testing, and certifying a system's ability to fail safely on a scale from weak to strong and provides instructions for improvement in the case of unsatisfactory performance.
IEEE	**IEEE 7010-2020** Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being	Recommended Practice	2020-05-01	Measures the impact (especially positive outcome) of artificial intelligence or autonomous and intelligent systems (A/IS) on humans using valid well-being indices. Includes product development guidance, identification of areas for improvement, risk management, performance assessment, and the identification of intended and unintended users, uses and impacts on human well-being of A/IS.
IEEE	**IEEE P7012** Standard for Machine Readable Personal Privacy Terms	Standard AI Systems	2017-12-06	Elaborates on ways in which personal privacy terms are given and how they can be read and approved by machines.

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Acronyms and Abbreviations

AAR	The Association of American Railroads
AI	Artificial Intelligence
APTA	American Public Transportation Association
BART	Bay Area Rapid Transit
BRT	Bus Rapid Transit
CV	Computer Vision
CNN	Convoluted Neural Network
CUTR	Center for Urban Transportation Research
DL	Deep Learning
DOT	Department of Transportation
EU	European Union
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEC	International Electrotechnical Commission
IEEE	The Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
LA METRO	Los Angeles County Metropolitan Transportation Authority
MARTA	Metropolitan Atlanta Rapid Transit Authority
MBTA	Massachusetts Bay Transportation Authority
ML	Machine Learning
NIH	National Institute of Health
NIST	National Institute of Standards and Technology
NN	Neural Network
NSA	National Security Agency
NTD	National Transit Database
NYCTA	New York City Transit Authority
RGB	Red-Green-Blue wavelength camera
RSSB	The Rail Safety and Standards Board
ROW	Right-of-Way
SAE	Society of Automotive Engineers
SDP	Standards Development Program
SEPTA	Southeastern Pennsylvania Transportation Authority
TriMet	Tri-County Metropolitan Transportation District of Oregon
UAS	Unmanned Aircraft System
USDOT	United States Department of Transportation
USF	University of South Florida
V2X	Vehicle-to-Everything
WMATA	Washington Metropolitan Area Transit Authority

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