FTA RESEARCH

FEDERAL TRANSIT ADMINISTRATION

2016 Safety Research Demonstration (SRD) Independent Evaluation

Interim Report

MAY 2020

FTA Report No. 0166
Federal Transit Administration

PREPARED BY
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U.S. Department of Transportation
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)		
^{o}F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^{o}C

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13. ABSTRACT
This Safety Research Demonstration (SRD) Interim Report provides the status of seven 2016 SRD projects selected to address the thematic areas of collision avoidance and mitigation and transit worker safety protections. It illustrates the process CUTR will use to perform the project and national-level program assessments. CUTR will present final assessment findings, outcomes of each 2016 SRD deployment, success of projects in meeting self-defined performance, national implications associated with deployment successes, and applicability to all public transportation operating environments in the final SRD evaluation report.

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Abstract

This Safety Research Demonstration (SRD) Interim Report provides the status of seven 2016 SRD projects selected to address the thematic areas of collision avoidance and mitigation, and transit worker safety protections. It illustrates the process CUTR will use to perform the project and national-level program assessments. CUTR will present final assessment findings, outcomes of each 2016 SRD deployment, success of projects in meeting self-defined performance, national implications associated with deployment successes, and applicability to all public transportation operating environments in the final SRD evaluation report.

EXECUTIVE SUMMARY

FTA's Transportation Innovative Improvement Program is authorized in Federal public transportation law (49 U.S.C. 5312(b)). The Safety Research and Demonstration (SRD) Program, which was developed under this authority, is a competitive demonstration opportunity under FTA's safety research emphasis area, in support of U.S. Department of Transportation safety goals. The SRD program provides technical and financial support for transit agencies to pursue innovative approaches to eliminate or mitigate known safety hazards through the demonstration of technologies and safer designs. SRD goals include:

- Advancing the development of materials, technologies, and safer designs to reduce the number of collisions and fatalities and mitigate the severity of transit-related injuries.
- Increasing the knowledge about the interface between machinery and people—both transit workers and passengers—to reduce the potential for safety-related incidents.
- Improving the safety culture at transit agencies, including stakeholder coordination and outreach.
- Supporting the development of transit safety standards, protocols, and best practices.

The University of South Florida and its Center for Urban Transportation Research (CUTR) is performing a project and SRD program level evaluation in accordance with the following objectives:

- Evaluate demonstration projects awarded to 2016 SRD grantees
- Assess the contribution of these projects towards advancing FTA SRD programmatic goals of improved collision avoidance and increased worker safety.
- Estimate the broader national-level impact of SRD projects.

CUTR is conducting a project-level evaluation based on the performance measures established by SRD grantees, which include:

- Los Angeles County Metropolitan Transportation Authority (LA Metro) – bus collision avoidance technology deployment
- Sacramento Regional Transit District (SacRT) – secondary track worker protection warning system
- Washington Metropolitan Area Transit Authority (WMATA) – secondary track worker protection warning system
- Chicago Transit Authority (CTA) – rail control center improvements
- Maryland Transit Administration (MTA) and New York Metropolitan Transportation Authority (NYMTA) – secondary track worker protection warning systems

- NYMTA – prototype street-side mirror for transit buses
- Pierce Transit – bus collision warning system and automated braking technology deployments

CUTR is engaged with the 2016 SRD grantees and will be using the data generated by the deployed technologies to independently evaluate the overall success of each project in meeting established performance measures, including 1) safety improvement; 2) system effectiveness; 3) return on investment; and 4) technology/knowledge transfer. CUTR will review any grantee-reported successes based on the performance measures and associated metrics and translate relevant findings into the overall program evaluation, highlighting any large-scale benefits reflected in the individual SRD project outcomes.

Although the program evaluation will not compare competing technologies or applications demonstrated in SRD projects, the broad assessment will be scaled to indicate national implications associated with technology deployment successes. The results of the evaluations and lessons learned from each project will support the continuous evaluation of the SRD program's national implications and benefits in addressing the thematic areas of Collision Avoidance and Mitigation and Transit Worker Safety Protections.

This SRD Interim Report summarizes each SRD project, includes the performance measures established by grantees for the projects, and provides lessons learned to date from grantees. CUTR will prepare a subsequent final report that will include the outcomes of each deployment including comprehensive lessons learned, the success of those projects in meeting self-defined performance, the national implications associated with deployment successes, and the applicability to all public transportation operating environments.

SECTION
1

Demonstration Program Description

The Safety Research and Demonstration (SRD) Program is part of a larger safety research effort at the U.S. Department of Transportation (USDOT) that provides technical and financial support for transit agencies to pursue innovative approaches to eliminate or mitigate safety hazards. The source of program funding is 49 U.S.C. Section 5312, which authorizes funding for research, development, demonstration, and deployment projects. The SRD program focuses on demonstration of technologies and safer designs. SRD goals include:

- Advancing the development of materials, technologies, and safer designs to reduce the number of collisions and fatalities and mitigate the severity of transit-related injuries.
- Increasing the knowledge about the interface between machinery and people—both transit workers and passengers—to reduce the potential for safety-related incidents.
- Improving the safety culture at transit agencies, including stakeholder coordination and outreach.
- Supporting the development of transit safety standards, protocols, and best practices.

USDOT's Federal Transit Administration (FTA) selects projects through a competitive process. On August 15, 2016, FTA's Office of Research, Demonstration and Innovation released a notice of funding opportunity (NOFO) soliciting project proposals to demonstrate innovative technologies and safer designs to improve public transportation safety. For this SRD project selection cycle, two thematic areas were established—1) projects that demonstrated collision avoidance and mitigation technologies and methods and 2) projects designed to improve transit worker safety. The specific objectives for the program are to assist transit agencies to:

- Explore advanced technologies[1] to prevent transit vehicle collisions
- Enhance safety of transit services
- Evaluate cost-effectiveness and practicability of potential solutions

On January 17, 2017, FTA announced the SRD program selections, which included the grantees listed in Table 1-1. Project descriptions reflect the original scope of work for each grantee. Many project scopes evolved during their implementation. These changes are reflected in the individual Section 3, Project Summaries and Status.

[1] Advanced technologies may include collision avoidance or awareness technologies, bus driver or pedestrian alert systems, and autonomous braking systems, as examples.

Table 1-1 *2016 SRD Grantees and Project Descriptions*

State	Project Grantee	Project Description	Funding Amount	Thematic Area
CA	Los Angeles County Metropolitan Transportation Authority (LA Metro)	Collision avoidance technology on up to 60 buses in active service. Selected systems will be deployed for 18 months	$1,450,000	Collision Avoidance & Mitigation
CA	Sacramento Regional Transit District (SacRT)	Secondary warning system for track worker protection with three-way communication between track, train operators, and dispatchers (deployed across entire light rail fleet).	$870,000	Worker Safety Protection
DC/ MD/VA	Washington Metropolitan Area Transit Authority (WMATA)	Worker protection system for employees working on or near tracks. System will include personal alert devices for track workers to wear that will communicate with devices mounted on both trains and the track, triangulating workers locations and issuing warnings to both track workers and rail operators when a train is approaching an active work zone (deployed on select locations in WMATA rail system).	$1,884,992	Worker Safety Protection
IL	Chicago Transit Authority (CTA)	Rail control center improvements to include new detection and alarm system, "Workers Ahead" status display, and improving QuickTrac display system to show potential red signal violations and status of traction power system ("loss of shunt").	$1,078,300	Worker Safety Protection
MD, NY	Maryland Transit Administration (MTA), New York Metropolitan Transportation Authority (NYMTA)	Research, develop, and demonstrate enhanced communication systems involving track workers and wearable alert units in Baltimore MTA's light rail system and New York City Transit's rail system.	$688,448	Worker Safety Protection
NY	NYMTA	Best practices for reducing blind spots and improving visibility for transit bus operators. Includes development of prototype street-side mirror design for transit buses.	$880,035	Collision Avoidance & Mitigation
WA	Pierce Transit	Collision avoidance warning system and automated braking features on system transit buses.	$1,664,894	Collision Avoidance & Mitigation
Total Awards Granted			**$8,516,669**	

SECTION

2

SRD Projects and Program Evaluation

FTA executed a cooperative agreement with the University of South Florida and its Center for Urban Transportation Research (CUTR) to perform this evaluation in accordance with the following objectives:

- Evaluate demonstration projects awarded to grantees identified in Table 1-1.
- Assess the contribution of these projects towards advancing FTA SRD programmatic goals of improved collision avoidance and increased worker safety.
- Estimate the broader national-level impact of SRD projects.

Project-Level Evaluation

CUTR is conducting a project-level evaluation based on the performance measures established by SRD award recipients. The project team is currently engaged with the 2016 SRD grantees and will be using the data generated by the deployed technologies to independently evaluate their performance measurement efforts. CUTR developed data collection plans (DCPs) for each SRD recipient to ensure the effective assessment of each project's impact on targeted performance measures and consistency with the overall SRD program evaluation.

Overall Program Evaluation

Although the SRD projects are expected to potentially generate relevant benefits, the implications of the societal benefits of large-scale adoption of pioneering research and development technologies will not be understood unless findings are generalized beyond single deployments. Each technology deployed and tested by SRD grantees has different applications and can have varying limitations and utility. CUTR will review any grantee-reported successes and translate relevant findings into the overall program evaluation, highlighting any large-scale benefits reflected in the individual SRD project outcomes.

The results of the assessment and lessons learned from each project will support the continuous assessment of national implications and benefits of the SRD program in addressing the thematic areas of Collision Avoidance and Mitigation and Transit Worker Safety Protections.

Although the program assessment will not compare competing technologies or applications, CUTR will perform a broad assessment scaled to indicate national implications associated with deployment successes. Addressing the question of successful applicability to all public transportation operating environments will be considered in the final SRD Evaluation Report.

Performance Measure Standardization

Tables 2-1 and 2-2 summarize the SRD program performance measures, definition/details, and data sources and collection frequency for the selected Roadway Worker Protection and Collision Avoidance and Mitigation projects. These standardized measures and associated data requirements are the basis for the DCPs and the project and program-level evaluations that are underway.

Table 2-1

Roadway Worker Protection Performance Measures

	Measure*	Definition/Details	Source	Frequency
1. Safety Improvement				
	1.1 Near miss	As determined by agency standards, violation of allowable minimum advanced warning that does not result in an injury and/or fatality	Database containing information of location, timing and speed of train and workers; reported as a rate; collected pre- and post-deployment**	Real-time data summarized on-demand
	1.2 Injuries		Agency reports	
	1.3 Fatalities		Agency reports	
2. System Effectiveness				
2.1 System Accuracy	2.1.1 False positives	Warning issued when no threat present	Database containing timestamp and location of warning with location of worker(s) and train	Real-time data summarized on-demand
	2.1.2 False negatives	No warning issued when threat was present		Real-time data summarized on-demand
2.2 System Acceptance	2.2.1 Acceptance	Perceptions and acceptance of use survey	Survey instrument issued during demonstration	Summary survey results
3. Return on Investment (ROI)				
	3.1 Unit costs, lifecycle, and installation costs	Unit costs of all system components	Transit agency and vendor records and invoices	
	3.2 Avoided costs	Property damages avoided, avoided maintenance	Agency records	

**Safety measurements should be collected pre- and post- deployment for demonstration locations.*
***If pre-deployment real-time data providing train speed, location, timestamp, and location data for roadway workers are not available, default to historical agency-reported near misses.*

Table 2-2

Collision Avoidance and Mitigation Performance Measures

	Measure	Definition/Details	Source	Frequency
1. Safety Improvement				
	1.1 Near miss	Event that had potential to lead to injury, fatality, or physical damage that was not actualized	Agency reports, database containing real-time location of bus and timestamped warnings	Real-time data summarized on-demand
	1.2 Injuries		Agency reports	
	1.3 Fatalities		Agency reports	
2. System Effectiveness				
2.1 System Accuracy	2.1.1 False positives	Warning issued when no threat present		Real-time data summarized on-demand
	2.1.2 False negatives	No warning issued when threat present		Real-time data summarized on-demand
2.2 System Acceptance	2.2.1 Acceptance	Perceptions and acceptance of use survey	Survey instrument issued during demonstration	Summary of survey results
3. Return on Investment				
	3.1 Unit costs, lifecycle, and installation costs	Unit costs of all system components	Transit agency and vendor records and invoices	
	3.2 Avoided costs	Property damages avoided, avoided maintenance	Claims and agency records for treated and control sample	Summary reports

SECTION 3

Project Summaries and Status

Fixed Location Train Detection and Worker Warning System

Maryland Transit Authority (Maryland MTA) and Metropolitan Transportation Authority (MTA) / New York City Transit (NYCT)

Project Description

Maryland MTA and its technology vendor, Miller Ingenuity, along with MTA/NYCT and its technology vendor, Metrom Rail, developed detailed plans to research, develop, and demonstrate an enhanced communication system involving track workers and wearable alert units in two locations:

- MTA light rail system
- MTA/NYCT's subway rail system

Technology Details

Miller Ingenuity Technology Components

Miller Ingenuity is demonstrating a fixed-location deployment of ZoneGuard, an electronic roadway worker protection (eRWP) system, on the entire length of Maryland MTA's at-grade light rail mainline. As a secondary roadway worker protection system, this technology is designed to provide a warning to roadway workers 25 seconds prior to light rail vehicle (LRV) arrival, in adherence to MTA's standard for minimum safe clearing time, and alert train operators when approaching work zones.

The ZoneGuard technology consists of the following components to establish a linear communication network:

- Train Detection Modules (TDMs) installed at strategic locations, including yard leads and spur/storage tracks, to register trains entering/exiting mainline track, with sensors for detection and monitoring of locations of all LRVs on mainline. In addition, a strobe kit drives a strobe up/downstream from work crews to notify train operators as they approach a work zone.
- Train Alert Modules (TAMs) placed between TDMs and near work crew that generate visual alarms for roadway workers when receiving a train approach

message from TDMs and provide reinforcement of train detections provided by TDMs via an on-board sensor

- WArN Wearables that alert workers when TDM signals an approaching train:
  - Employ-in-Charge (EIC) wearable – a special wearable device with precautionary test to ensure that all workers are protected
  - Watchman/Lookout Wearable (WLW)
  - Worker Wearable (WW), with "confirm" button

Each TDM and TAM includes an internal GPS module and antenna to maintain accurate time across all devices for logging purposes and to provide device location information for train detections and track profile configuration. Each TDM and TAM also includes cellular modems to allow for a remote connection to download logs and firmware/configuration updates. The TDMs and TAMs installed at MTA are paired with an auxiliary Power Box and a solar panel for recharging.

Workers join the communication network through a synchronization process that is initiated by the roadway worker in charge (RWIC). Each powered-on WLW or WW in the vicinity of a RWIC during the synchronization process will be synced into the ZoneGuard network. When a TDM detects an LRV, it issues a warning onto the network to neighboring TDMs and TAMs. When workers sync to the network, their location relative to specific TDMs and TAMs is known. Based on the LRV maximum allowable speed, a 25-second warning is sent to each wearable in the work group.

Upon a warning, each worker in the group must clear to their specified safe zone and then clear their WWs or WLWs individual local alert to silence the wearable's alarm. Once the train has cleared the work zone, the RWIC may clear the Global Alert on the network. If the Global Alert is not cleared by the RWIC, a TDM down the line will detect the LRV and automatically clear the Global Alert. Once the Global Alert has been cleared and no new alerts have been generated, work on the track may resume.

In addition, onboard devices have been installed on MTA's LRVs. Although not required by the ZoneGuard eRWP system, the onboard devices provide warnings to LRV operators and record exact GPS location information of each LRV, which is documented in the ZoneGuard web portal.

Metrom Rail Technology Components

NYCT's Office of Strategic Innovation and Technology evaluated Metrom Rail's AURA Roadway Worker Protection Systems (RWPS) technology on a demonstration track. The purpose of the Proof of Concept demonstration was to evaluate if the AURA RWPS system could provide workers with a minimum

15-second advanced warning of approaching trains in two configurations. Metrom Rail demonstrated and evaluated two alternative methods of deploying its AURA system.[2] The first method consisted of one wayside module communicating with a train, and the second system used three wayside modules, each communicating a work zone to a train. Worker safety vests were equipped with Personnel Modules (PM) that activated the work zones. Technology components included:

- Two train antennas to provide distance and communication to the wayside. Metrom Rail's AURA RWPS uses Ultra-Wide Band (UWB) technology that operates at 3.1–5.2GHz.
- One UWB Wayside Module (WM) with antennas to transmit distance and communication data to the train through:
  - An individual WM located on wayside in the middle of a work crew to communicate with the train and, according to its speed, provide a 15-second advance warning to workers and train operator by generating an audible alarm and visual strobe on the wayside and providing audible alerts and visual strobes issued to PMs within a zone.
  - Three WMs installed along evenly spaced intervals to identify and notify PMs of 15 second incursions; a work zone is established as workers enter a check point.
- PMs provide vibration, audible warning tone, and color strobe light when WMs identify a 15-second incursion; workers must confirm the alarm, which silences both PMs and WMs.
- A User Interface Module (UIM) to inform train operators of the number of workers present within the work zone, distance of the train from those workers, and how many workers confirmed their alarm. Train operators must also confirm to silence the alarm.
- A control module to provide central connection, diagnostic status, and logged events storage for the train-borne modules.

Metrom Rail's AURA RWPS modules use radio transceivers that use a speed-based alarm algorithm, calculating the distance and closing rate between modules. When a programmable alarm limit is exceeded by either a distance or time value, alarms are initiated for both the worker and the train operator. The speed-based alarm algorithms ensure that workers receive consistent alarm times regardless of train or vehicle speed, which potentially minimize false alarms and offer more flexibility in warning time alerts. The system will alarm only in a situation in which the distance between the worker and the rail vehicle is decreasing to further reduce the potential for false alarms.

[2] The complete AURA system includes the Worker Protection System, Positive Train Control, and Collision Avoidance System.

Metrom Rail's Worker Protection Vest incorporates dual UWB antenna to provide maximum coverage to the worker. The vest performs a diagnostic self–check hourly and continuously flashes a green LED if the vest is fully operational. Visual and audible alerts are emitted to the worker in the event of a vest malfunction.

Figure 3-1

Train antenna module

Figure 3-2

Wayside modules

Figure 3-3

Train control module

Figure 3-4

Worker protection vest

Progress and Evaluation

FTA conducted a kickoff meeting with the grantees and CUTR in October 2017, and CUTR sent the DCPs to both grantees (Maryland MTA and NYCT) in January 2018. Appendix A details the performance measures by evaluation category.

In November 2018, Metrom Rail released the Proof of Concept Demonstration Report reflecting initial system testing performed in July 2018 in Brooklyn, New York, on the G Line between 4th and 7th avenues. The Metrom Rail's AURA RWPS successfully demonstrated that train operators and workers in a work zone were warned at least 15 seconds prior to the train's arrival. In addition, train operators received a visual alarm notice at least 15 seconds before zone entrance. All systems communicated during the demonstration.

NYCT issued a final draft project report in January 2019. In June 2019, NYCT provided documentation developed as part of the Proof of Concept, including an executive summary, a cost-share report, and the final report, which CUTR will use for the project evaluation.

Maryland MTA and Miller Ingenuity completed their testing phase in February 2019, and the installation of all relevant train detection units was completed in August 2019. The system is now fully functional.

In the early phase of deployment, alerts were generated based on TDM detections and the maximum allowable speed of each track segment. Subsequently, Miller Ingenuity deployed a firmware update, which uses a combination of TDM detections and LRV/wearable GPS location to generate precise alerts at a configured time. In addition, Miller Ingenuity established a web portal and configured the TAM and TDM units to communicate with the web portal. In February 2020, Maryland MTA and Miller Ingenuity provided CUTR access to the data portal. CUTR will use the data collected and maintained within the portal to conduct performance evaluation.

Lessons Learned

During the transition from system design to implementation, Maryland MTA and NYMTA learned relevant lessons leading to improvements of the technology.

- During equipment installation and testing, the radio communication signal was dampened by the presence of trees and building infrastructure obstructing the line of sight between the various units (TAMs and TDMs). This required the installation of additional units beyond the grantee's initial estimates. The line-of-sight distance is an important indicator of solid communication, which is also verified by received signal strength indicator (RSSI) data provided in the system's log files.
- In the early stages of deployment, MTA installed an infrared camera to verify that the sensors and sensing algorithms were detecting trains while ignoring the presence of objects other than trains. Data collection and analysis revealed that the use of the infrared camera proved to be unrealistic, as analyzing the pixel data caused a significant lag in confirming and communicating a train detection and sun glare and inclement weather influenced the camera's performance. The camera was subsequently removed, which also contributed to saving power.
- The equipment relies on solar power to function. During the winter months and reduced sunlight, the solar panels did not receive enough sunlight to fully recharge the units. Over extended periods of cloud cover, this could lead to unit discharge and power shutdown, with units not powering back on until recharged to a minimum power-up level. Miller Ingenuity and MTA are discussing permanent power solutions.

- TDMs were originally installed at every station at MTA. After data collection and observation, it was found that when a train was stationed on the track adjacent to the TDM, a second train coming to the station from the farther track would go undetected due to the line-of-sight blockage from the stationed train. This required further layout reconfigurations of TDMs and TAMS.
- Metrom Rail's AURA RWPS Proof of Concept at NYMTA exhibited the ability to provide a 15 second warning to track workers in multiple operating environments, including underground and elevated environments.
- Metrom Rail's AURA RWPS Proof of Concept revealed the necessity for rail worker vests to be equipped with at least two UWB radio-based antenna to ensure that track workers are equipped with enough detection and warning capabilities.
- NYMTA considers the AURA RWPS as a technology that is complementary to existing procedures and systems.

Track Inspector Location Awareness with Enhanced Transit Worker Protection

Washington Metropolitan Area Transit Authority (WMATA)

Project Description

WMATA, along with its technology vendor, Protran Technology (Protran), developed a plan to research and demonstrate a worker protection system with an enhanced track inspector location awareness that communicates key safety information to the dispatcher. Although originally deployed only at high-risk locations, in 2018 WMATA determined that a deployment along the entire Red Line would allow a better evaluation of the technology. In addition to further validating the system's intended functionality, an end-to-end deployment would serve to test actual human behavior response that occurs over a broad range of possible operating environments while the system is under continued use and not just in high-risk areas. A full line implementation would also allow for the collection of actual worker location data in operating conditions for further analysis on worker efficiency, safety trends, and rule adherence. WMATA's Red Line was chosen for this phase, as it is a self-contained operating system that does not share concurrent track with any other lines.

In August 2019, WMATA developed a revised scope that delineated the following phases of the demonstration:

- Phase 1, Demonstration on WMATA Hot Spots corresponds to the original FTA SRD scope that planned the installation of 15 train sensors on 13 selected locations. This phase is complete and served to inform Phase 2 (i.e., scope expansion).

- Phase 2, Red Line Installation and Pilot Testing considers the installation and testing of the technology on the entire Red Line.

Technology Details

The Protran system is designed to provide a secondary warning system to mitigate rail vehicle and wayside worker accidents. The system was conceived and designed as a non-critical, redundant, secondary solution that provides an additional layer of protection to workers. The intent is to facilitate and automate compliance with existing roadway worker protection rules.

The technology uses a chain of wireless wayside transponder devices (wayside devices), as shown in Figures 3-5 and 3-6, installed along the right-of-way every 600–800 feet, on average. These devices communicate between themselves and with wearable armband devices worn by workers on the track. The communication between the wayside devices occurs in a so-called daisy-chain configuration via a wireless spread spectrum radio frequency that is native to the system and does not interfere with any other systems installed wayside. When workers wearing the armband devices are present on the track, the wayside devices in proximity to the workers display flashing amber strobe lights up track and down track from where the workers are located. As the workers move along the track, the lights continue to "follow" the workers. The flashing lights serve as a visual signal to approaching train operators that workers are present. When operators enter a zone in which they see the flashing amber lights, they are required to decelerate the train to a safe speed.

Figure 3-5

Wayside unit transponder device

Figure 3-6

Wayside unit installed in WMATA tunnel environment

In addition, optical sensors are mounted on each wayside device and are positioned to automatically detect train vehicles approaching zones where workers are present. When the Protran system detects a vehicle approaching a zone where workers are present, the system causes worker armbands to vibrate, light up, and emit a warning sound. This is the signal for workers to immediately clear the roadway and move to a place of safety, as a train is approaching their location. The system is configured to provide ample time for workers to leave the tracks, taking into consideration the speed commands issued to vehicles in the vicinity.

The system features a back-end software package that allows users on a computer to view worker locations, movements, and times of entry and exit to and from the roadway. Worker location data are captured by the wayside devices wirelessly tracking the movement of the armbands, and the data are transmitted to a cloud database via a hardwire connection on station platforms. The data collected can be viewed either in real time or *post facto*.

Progress and Evaluation

FTA conducted a kickoff meeting with the grantees and CUTR in October 2017, and CUTR sent the draft DCP in April 2018 and a revised version in February 2019 to account for changes in the overall deployment. Appendix B reports the performance measures by evaluation category.

Following the initial plan, WMATA installed the system at 13 high-risk locations with specific features presenting a heightened risk to track workers, such as vertical curves, horizontal curves, and blind spots. One recognized challenge was that these locations were not in physical proximity to one another; instead, they were dispersed all around the WMATA system and were generally limited to 1–2 station segments. Testing commenced in July 2018 to validate the operational readiness and the above-mentioned functional features of the system and test the data transfer capabilities of the wayside infrastructure to a remote backend server.

Ultimately, deployment along the 13 locations did not allow for proper demonstration of the system's effectiveness during revenue operations. Workers and train operators moving in, around, and through the test locations would have to remain cognizant of the zones in which the system was installed and those where it was not, creating difficulties in remembering to configure their wearable armband devices accordingly. In addition, train operators could encounter two different potential wayside worker notification scenarios as they moved in and out of the zones in question. Although these issues could be partially mitigated with robust training, in-field monitoring, and compliance testing, it was concluded that the use of the 13 test zones in regular operations would leave too many human-factor safety issues unaccounted for.

Following the decision to deploy the system on the entire Red Line, installation began in March 2019. A total of 514 wayside devices were installed on the mainline sections of the Red Line, inclusive of 31.9 miles (63.8 miles of single track) by September 2019.

In October 2019, CUTR participated in a site visit to WMATA to discuss the project progress in detail, learn more about the data to be collected, and gain some clarification on the independent evaluation data collection. Although the data collection process is expected to last nine months, several challenges remain in terms of how data will be extracted from the equipment, stored, and used for the evaluation. CUTR is continuing discussions with the grantee and vendor regarding data access and the level of data available.

As of March 2020, the wayside units spacing requirements and the above system reliability issues remain under study and review jointly by both Protran and WMATA. Reconfiguration of the devices, re-engineering of one-off zones with unique circumstances, and completing system testing of installed system components will continue well into calendar year 2020. Once the devices are properly configured and tested, an operational demonstration on workers during revenue hours on the Red Line can begin.

Lessons Learned

The initial testing and subsequent extension of the installation on the entire Red Line provided WMATA with important lessons learned about the advantages and constraints of deploying a prototype technology on existing infrastructure:

- The deployment of a safety system in various disparate and unconnected locations does not allow for proper demonstrations of system effectiveness during revenue operations.
- The wayside device spacing plays a significant role in the reliably of the detection of passing rail bound vehicles. The system was originally configured on the assumption that the wayside devices would be installed at a uniform distance of 800 feet between one another to ensure system effectiveness; however, when installing the units on the system, their ultimate location was

a function of where power sources were available, resulting in an average non-uniform unit spacing of about 670 feet. This led to reassessment and review of the parameters governing warning distances and warning times required to keep workers safe.

- Power source availability dictates wayside device installation increments, which ultimately plays a role in the parameters governing warning distances and times.
- The performance and effectiveness of wayside units can be affected by bulkheads, alcoves, and pillars along the railway.
- System parameters governing how the system responds during long vehicle dwell times, especially at train station platforms, is under assessment and review.
- The impact of environmental factors such as moisture, vegetation, and dirt build-up are under assessment and review.
- The wayside devices are designed to be fail-safe and provide notification whenever a wayside device is not responding. However, the impact of malfunctions in sub-components of the wayside devices, including failures of the optical sensors or failures of the flashing strobe lights, is under assessment.
- Asset management and monitoring of the 514 installed wayside units along 32 miles of restricted right-of-way, both in tunnels and open air, can be complex and cumbersome. Currently, any re-configuration of wayside units requires getting track time and sending workers directly to the unit on the wayside. The ability to remotely monitor and configure units could potentially simplify overall management of the system.
- System reliability requires software with self-diagnostic capabilities to receive real-time information on failures occurring in the system hardware.
- System testing revealed several issues, identified by both Protran and WMATA, that necessitated a re configuration of previously-installed wayside devices and train sensors.

Enhanced Employee Protection Warning System including Roadway Worker Protection

Sacramento Regional Transit (SacRT)

Project Description

SacRT, along with its technology vendor, Protran, developed detailed plans to research, develop, and demonstrate a project with two phases—an Enhanced Employee Protection Warning System (EEPWS) and a Dispatcher/Employee-In-Charge Software Program (D/EICSP)—at two locations on the light rail line.

Technology Details

The D/EICSP is designed to initiate a warning and confirmation between all transit workers and employees in charge, including dispatchers and train operators. The electronic, numerical "handshake" confirms that workers are clear of the track and that service is live.

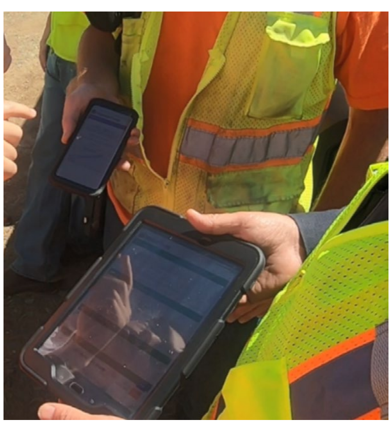
To develop and demonstrate the EEPWS and D/EICSP, SacRT installed vehicle-mounted advance warning devices in the cabs of each grantee's 97 light rail vehicles (LRVs). The advance warning device alerts the train operator that the train is approaching a work zone and alerts workers within the work zone of the approaching train using a volume-adjustable audible alert ranging of 66–94 decibels at 3 feet. The train-mounted unit is enclosed in polycarbonate and can function in operating temperatures ranging from -40 to +185 °F.[3]

The EEPWS also includes a personal alert device, shown in Figure 3-7, for advance warning of an approaching train through a 94-decibel audible alert when the train is 800–3000 feet, allowing at least 15 seconds of advanced warning.

Figure 3-7
Personal alert device

The D/EICSP technology, shown in Figure 3-8, allows for a secondary protection to be implemented when a work zone needs to be established. This software is installed on handheld mobile devices that the crews use to secure and release work zone restrictions on train movement.

Figure 3-8
D/EICSP technology



[3] https://www.protrantechnology.com/rail/safety/roadway-worker.

Progress and Evaluation

FTA conducted a kickoff meeting with the grantees and CUTR in September 2017, and CUTR sent the DCP in April 2018 and a revised version in March 2019. Appendix C lists the performance measures by evaluation category. SacRT provided details to CUTR on the data collection methods in place, which led to DCP revisions due to identified lack of geocoded data available from wearable devices. SacRT is collecting incident performance measures using a manual input method and logging system (an Excel file titled "Protran Incident Tracker") to record operator and roadway worker-reported false positives and false negatives.

CUTR participated in a site visit in July 2019 to discuss the data to be collected, perform an initial review the SacRT's employee feedback survey, and inspect the use of SacRT's legacy technology (E/EICSP).

In September 2019, the agency developed an employee survey to collect employee feedback on the D/EICSP. CUTR reviewed the survey and provided suggested revisions. Once installation and testing have concluded, SacRT will perform data collection and activities for nine months.

Project advancement has been delayed due to unforeseen software capabilities. In December 2019, Protran sent instructions to SacRT to improve the setup of the EEPWS by adding software on the D/EICSP handheld device. CPUC restrictions on handheld device usage by track workers required blocking software be implemented to prevent the D/EICSP handheld device from accessing any programs other than the intended EEPWS. More information on this restriction is detailed in the Section 4, Lessons Learned. Protran worked with the software company and loaded the software onto the platform for SacRT units, and SacRT staff are working to install the newly-revised software and plan to begin testing early in 2020.

Lessons Learned

The deployment of EEPWS along the SacRT light rail system provided the agency with lessons learned about the level of maturity of the technology, the constraints presented by existing legacy systems, and unexpected institutional or regulatory barriers to deployment:

- First-generation technology deployments often expose unknown equipment limitations. SacRT encountered challenges associated to the capabilities of the first generation of the technology that was deployed, including difficulties with triggering of alerts and false positive alerts due to the operating environment. The realization of these limitations led the technology vendor to develop newer versions of the piloted technology, which are now available on the market. However, those new technologies are not the subject of this research demonstration project. It is important for grantees to understand which version of the technology they will be testing and deploying and the limitations of that generation of the technology.

- Tracking software revisions with a change report would help streamline the validation and approval process associated with revisions.
- Agencies deploying technologies should consider local regulatory requirements in all phases to reduce or remove the lengthy delays associated with testing and validation. SacRT and CPUC conducted a review of the EEPWS and found compliance concerns with the abilities of the operating system on the devices. While activated, the software allowed access to all programs and applications on the smart devices. This differed from the original version of the software that blocked access to all other applications on the handheld device. This software failure caused testing concerns due to the direct conflict with CPUC General Orders 172 and 175-A, which govern the use of personal electronic devices by employees of rail transit agencies and govern roadway worker protection provided by rail transit agencies respectively.

Operations Control Center Safety Enhancements

Chicago Transit Authority (CTA)

Project Description

CTA initiated the Operations Control Center Safety Enhancements project to research, develop, and demonstrate a system-wide rail project to enhance control center safety operations. The project includes the development and evaluation of four control center components:

- The *Loss-of-Shunt Tool* advanced and expanded the utility of the tool originally developed through a joint CTA and American Public Transportation Association (APTA) pilot. The tool will harness QuicTrac data currently used at CTA's control center to alert if there is a failure to detect the presence of a train over a section of track, i.e., loss of shunt.
- *Communication between the current wayside worker protection system and control center* – CTA currently has a wayside worker protection system installed on portions of track with train operator visibility concerns. The system consists of flashing wayside signals and cab signal downgrades that are initiated when workers turn on the system. CTA is linking the current system to the control center for the primary purpose of reducing false positives. Once connected, when workers turn on the system, their active status is transmitted to the QuicTrac display, allowing operators at the control center to be aware of the work zone and potentially turn off the system if workers have left the zone without turning off the protection system.

- A *red signal violation alarm*, according to logic statements applied to the QuicTrac data, will trigger an alarm at the control center.
- A *traction power status overlay* on the QuicTrac display is being developed to capture traction power status, indicating to the control center operator any trains that are experiencing loss of traction power over segments of the track.

Technology Details

The four control center components rely on several tools and systems:

- *Track Circuit Monitoring (TCM)* provides a means for CTA to identify abnormal track circuit conditions affecting daily operations through the following design principles:
  - Uses status information to analyze track circuits in real time to detect irregular operation.
  - Applies algorithms that include wayside and train specific parameters to determine the physical location of a train.
  - Can be programmed to assess the most severe problems for investigation, so resources can be managed efficiently.
- *Red Signal Overrun (RSO)* provides a means for CTA to identify and track signal violation through the following design principles:
  - Modified the supervisory control and data acquisition (SCADA) server at 59th Junction and Open Platform Communications (OPC) server at Paulina Junction to pass on new signal aspect indications and RSO alarm inputs; these inputs are wired into SCADA and passed to the QuicTrac database.
  - Designed a graphic of signal aspects for each signal at Paulina and 59th Junction interlockings.
  - As of March 2020, four signals were added at the 59th Junction on the Green line, and functional testing is underway.
  - Modified QuicTrac to provide a pop-up alarm when an RSO event is detected.
- *Worker Ahead (WA)* provides a means for CTA to track roadway worker crews through the following design principles:
  - Developed QuicTrac graphics for WA signals (indicating normal and red alarm status) and visual display of WA zones.
  - Modified QuicTrac database to link indications of WA zones with the developed graphics.
  - WA protocols and functionality testing developed by CTA (currently underway on the Blue Line).

Progress and Evaluation

FTA conducted a kickoff meeting with the grantees and CUTR in September 2017, and CUTR sent the draft DCP to CTA in September 2018. Appendix D lists the performance measures by evaluation category. Once system integration and development are completed, CTA will perform six months of data collection, scheduled to conclude in late summer 2020.

The TCM was first implemented on the Red and Blue lines in April 2019. To date, CTA has seen a 72.5% decrease in alarms, the result of refining the implementation of the system and finding and fixing potential field and/or SCADA anomalies. Currently, CTA aims to continue the trend of decreasing alarm frequencies by pinpointing certain trouble areas using the tool and producing timely solutions. In addition, field-testing for both the red signal overrun and WA overlay systems is underway and expected to be complete in summer 2020.

Lessons Learned

The analysis of data collected over the course of project implementation provided an indication that the technology is contributing to improved safety and reliability of CTA daily operations along the Red and Blue lines. Among the lessons learned are the following:

- Identifying track structure anomalies prior to an event can reduce potential service interruption times through proactive mitigation implementation.
- As the track circuit monitoring system identified potential track issues, trouble areas were quickly addressed, and the implementation of the technology was refined to reduce the frequency of alerts. Additionally, the software for the red signal overrun is also being updated to reduce the volume of false positive alerts.
- Technology refinements may be necessary in the implementation phase of the project to ensure the volume of alarms provided is not burdensome.
- False positive alerts reduce the efficiency of red signal overrun technology.

Bus Collision Avoidance and Mitigation

Pierce Transit

Project Description

The Pierce Transit Collision Avoidance and Mitigation Safety Research and Demonstration Project includes the installation and demonstration of the Pedestrian Avoidance Safety System (PASS), which uses light detection and ranging (LiDAR) sensors to trigger an automated deceleration and braking system.

When initially scoped, an existing collision avoidance warning system (CAWS) was to be used to trigger a separate automated emergency braking (AEB) system. The original CAWS vendor and the grantee were unable to reach an agreement on contractual issues; therefore, the vendor did not participate in the project. The PASS system vendor agreed to undertake the development of the sensor package to trigger deceleration and braking.

The current scope of work for the project includes five phases:

- Phase A, Test Planning, Instrumentation, and Documentation
  - Project management setup, work plan development, public board actions, and contract execution
  - Site visits and facility surveys at Pierce Transit and the Virginia Tech Transportation Institute (VTTI)
  - Development of safety, installation, and test plans
  - Delivery of a Pierce Transit bus to VTTI's Smart Road test track in Blacksburg, VA
- Phase B, Closed-Course Alpha Testing and Passenger Motion Testing
  - Development of test scripts for collision avoidance maneuvers
  - Equipping the first bus with PASS collision avoidance system
  - Testing of collision avoidance system on test track
  - Testing of collision avoidance system under rain and fog on test track
  - Development of passenger motion testing methodology
- Phase C, In-Service Engineering and Data Collection Testing
  - Development of on-board video processing for detection of false positives and false negatives
  - Installation of three additional PASS systems for initial systems testing and engineering modifications at Pierce Transit
  - Development of driver survey questionnaires
  - Return of bus to Pierce Transit from VTTI
- Phase D, Revenue Service Field Demonstration
  - Development of data collection, storage, and analysis systems
  - Installation of PASS collision avoidance systems on 26 additional buses, for a total of 30
  - Operation of buses in revenue service in data collection mode only (stealth mode)
  - Training and surveying of drivers
  - Operation of buses in active mode and collect data

- Phase E, Project Reporting and Evaluation
  - Reporting on driver acceptance and system performance
  - Reporting on economic return on investment
  - Undertaking knowledge transfer and outreach activities
  - Preparation of interim and final reports

Technology Details

The PASS is designed to assist bus drivers through early detection of potential collisions with vehicles and vulnerable road users (VRUs) accompanied by automatic initiation of deceleration and braking. PASS uses LiDAR sensors to detect objects and an innovative method to decelerate the bus by using existing braking functionality that normally is used to immobilize the bus while doors are open to board and alight passengers. Figures 3-9 and 3-10 show the sensor array configuration and mounting on the front of a bus.

Each bus equipped with PASS will also be equipped with a data logger to record and transmit to a server event records comprising event timestamp, GPS coordinates, speed, heading, lateral and longitudinal acceleration rates, yaw rate, distance to object, relative speed of object, brake status message, throttle status message, and PASS operating mode.

Figure 3-9

PASS lidar sensor assembly

Drawing courtesy of DCS, Inc.

Figure 3-10

PASS sensor assembly attached to Pierce Transit bus #230

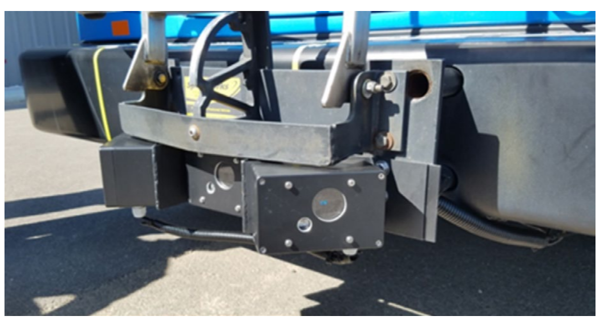


Photo credit: J Lutin

Progress and Evaluation

FTA conducted a kickoff meeting with the grantees and CUTR in October 2017, and CUTR sent the final DCP to Pierce Transit in February 2018. Appendix E reports the performance measures by evaluation category.

Pierce Transit and its technology vendor have completed Phases A and B. The alpha testing performed in Phase B included shipping a Pierce Transit bus to Blacksburg for closed-course testing of PASS on VTTI's Smart Road facility. Figure 3-11 shows a collision avoidance test with a VRU at VTTI.

Figure 3-11

VRU collision avoidance test

Photo credit: Andrew Klum, VTTI

In addition, VTTI developed a passenger motion testing system to observe, measure, and analyze the impact of manual and automated braking on passengers. The goal is to inform a standard for autonomous braking for buses. The system was configured and verified and will be used during testing at Pierce. VTTI's Smart Road Facility testing has concluded, and the bus used in the testing has been returned to Pierce Transit.

Phase C is currently underway and is scheduled to conclude in April 2020. The bus tested at VTTI, along with three additional buses have been equipped with PASS and will be equipped with Transit Event Logging System (TELS) video processers developed by University of Washington's (UW) Smart Transportation Applications and Research Lab (STAR Lab). TELS will be used to evaluate the incidence of false positives and false negatives for the PASS system. TELS can recognize and track objects using an on-board forward-facing camera and monitor potential bus-vehicle and bus-pedestrian near-miss events. The TELS system was implemented on an Internet-of-Things (IoT) device relying on advanced graphics processing units.

The design of the TELS processing pipeline and algorithms for video detection and data transmission considers the need for real-time operation and high reliability. The design includes onboard artificial intelligence and real-time event recording. The system input video feed is from the Apollo system mounted on the bus. Pierce Transit's Data Collection and Management Plan further describes the technical aspects of the data logging and associated systems.

Upon successful completion of in-service engineering testing of the initial four buses, Phase D will be initiated with an additional 26 buses equipped with PASS. All 30 buses will be monitored using the PASS data-loggers and telematics for a year-long demonstration. Phase D is scheduled to conclude by July 2021.

VTTI developed a bus operator self-reporting survey that will be administered three times during the demonstration. The survey addresses system activity, trust ratings, and route type, which will facilitate the assessment of bus operator attitudes and acceptance of the DCS PASS-CAWS/AEB technologies.

On October 30, 2019, UW provided a revised data collection and management plan. This document details the data generation, data elements, data flow and storage. Until all buses are equipped with the PASS system, all data generated will be collected by vendor. Once installation is complete, data collection and storage will be handled by UW using a local server with a Microsoft SQL database. Details on how the system performance measures will be generated and provided to CUTR for the independent evaluation have yet to be determined.

Lessons Learned

The lessons learned reported by the grantee are related to conducting research in the transit environment, retrofitting buses with advanced technology, and the data collection and management from multiple sources.

- Champions for transit research projects are needed at the highest levels of the agency. Executive-level support ensures that time and financial investments will continue throughout all phases of the project.
- Contract negotiations with the technology vendor and obtaining necessary approvals from boards or other stakeholders take time. It is important that grantees take that necessary negotiation and approval time into consideration when the project is in the development phase. The frequency of board meetings is another factor contributing to potential delays in project implementation.
- Scope changes have the potential to lead to the need for additional expertise and/or testing facilities. Scope chances potentially introduce several challenges, such as the need for additional subject matter experts or additional testing facilities. When initially conceived, the original collision avoidance warning system had already been developed; however, when the original technology vendor and the grantee were unable to reach an agreement on contractual issues, the project scope changed to allow the PASS system technology vendor to undertake the development of the sensor package to trigger deceleration and braking. This change led to the need for an additional testing facility, which was not part of the initial scope.

- Building hardware and software systems for retrofit and use in a legacy bus presents different challenges than building stationary systems or integrating systems into new automotive designs. The placement of the sensors, especially in reference to the placement of the bicycle racks on the front of the buses, led to innovative placement solutions to ensure that the technology could capture the necessary data without interference from equipment causing unintended false positive alerts.
- Ongoing challenges identified by Pierce Transit are related to the ability to have data that are concurrently and consistently collected to allow for meaningful data analytics. This includes the "self-reporting" construct of the employee surveys and the difficulties in the connection of the Jetson system to the Apollo camera for concurrent data collection and transmission.

Transit Bus Mirror Configuration Safety Research and Development

New York City Transit Department of Buses (NYCT DOB)

Project Description

NYCT DOB and its partners in research VTTI and technology vendors Safe Fleet, New Flyer, and RECARO Seating developed a plan to research, develop, and demonstrate design modifications to the bus operator street and curbside mirrors on transit and motor coach buses. The plan also involves developing and demonstrating design modifications to the street-side mirrors on transit buses. The purpose of the modifications is to improve pedestrian, bicyclist, and customer safety by adjusting the placement and size of mirrors with the intent to minimize the A-pillar obscuration. The Transit Bus Mirror Configuration Safety Research and Development project began on September 18, 2017 and is scheduled to end on September 17, 2020.

The primary goal of this project is to identify visibility requirements for transit bus mirrors and demonstrate safety and bus operator acceptance. VTTI will identify mirror design parameters that satisfy optimal mirror and direct visibility, seek expert and user input, and deliver make/model-agnostic mirror visibility performance guidelines. In addition, NCYT and VTTI will determine design effectiveness and bus operator acceptance during the field demonstration of mirror prototypes (i.e., 30 buses over 6 months).

The project includes significant stakeholder coordination and points of input. Stakeholders include NYCT, bus operators and other agency personnel, New Flyer, the National Highway Traffic Safety Administration (NHTSA), and FTA. VTTI is gathering stakeholder input through employee surveys and a robust advisory panel approach that includes the following focus groups:

- Management and training supervisors
- Low-floor transit bus operators
- Express coach bus operators

NYCT and VTTI will document stakeholder input, including surveys and post focus group questionnaires, to effectively and accurately address design and operational concerns and overall acceptance.

Mirror Assembly and Specification Details

The result of the vehicle analysis and research led to a set of mirror assembly guidelines and specifications for street-side mirrors as well as a complete set of direct and mirror visibility guidelines. The design goals and mirror design guidelines and specifications applied to the optimized mirror design for evaluation and demonstration include the following:

- Design Optimization Goals:
  - Maximize forward/street-side direct visibility around mirror head and pillar.
  - No obstruction of mirror faces from bus body.
  - Provide rear/street-side mirror visibility of the adjacent lane from a point on the ground at the bus front axle rearward of the rear bumper including the horizon.
  - Provide rear/street-side mirror visibility of the second lane from a point on the ground at the bus front axle rearward of the rear bumper including the horizon.
  - Provide a range of mirror face adjustments and rear visibility that meets accommodation needs of 95% of bus operators (i.e., 2.5th percentile female to 97.5th percentile male eyepoints).
  - Fold-away design for survival on street and bus wash.
- Optimized Mirror Guidelines:
  - Mirror(s) should be heated to avoid ice build-up during cold climate operations.
  - Mirror face(s) should be adjustable via interior switches or manually by the bus operator by reaching from driver seat.
  - Mirror head should be fixed in a single optimized functional location relative to the mirror arm, and the mirror arm should not slip within the bus body fixture housing. Mirrors should be braced and clamped so that vibration will not blur the view while the bus is idling and operating at speed.
  - Mirror head should spring away or fold away when struck by an object, and it should not strike the bus body or any glazing. A quick reconnect

feature should be present that allows bus operators to return the mirror head to its optimal position without the use of tools.

- Optimized Semi-curved Mirror Specifications:
  - Reflective face, semi-curved, surface area – 53,500 mm^2 to 57,500 mm^2
  - Reflective face, semi-curved, radius – 1,200 mm to 1,300 mm radius
  - Reflective face adjustment angle limit to +/- 10 degrees vertical and horizontal from nominal center
  - Mirror head assembly should not create continuous obstruction with pillar such that a cylinder with a diameter of 304.8 mm should be visible between the mirror head and pillar.

Progress and Evaluation

FTA conducted a kickoff meeting with the grantees and CUTR in October 2017, and CUTR sent the DCP to NYCT/VTTI in March 2018 and finalized the plan in March 2019. Appendix F reports the performance measures by evaluation category.

Since inception, the project team conducted the following activities:

- Collection of expert opinions on transit bus visibility for the largest transit authority in the U.S., including representatives from management and training supervisors, low-floor transit bus operators, and express coach bus operators.
- Detailed reverse engineering benchmarking of the bus operator workstation, door and forward glass surfaces, and all interior and exterior mirror surfaces on four distinct low-floor transit bus makes/models and two distinct express coach bus makes/models with the assistance of New Flyer and Recaro.
- Analysis on all six vehicle models of forward visibility (including door glass) and rear visibility on a scaled replica of a busy NYC intersection for bus operators based on 95% accommodation (rather than the traditional 90% accommodation) of a recent, broad, and diverse U.S. anthropometric population sample.
- Development of a low-floor transit bus mirror visibility design guide that includes benchmarking feature values for the range of measured buses.
- Static bus operator evaluation of the first iteration of three optimized mirror designs, leading to the selection of a single optimal design for further dynamic pilot evaluation and refinement for the field demonstration with the aid of Safe Fleet.

Figure 3-12 shows the current iteration of the optimized semi-curved mirror design that is planned for manager and bus operator dynamic pilot tests.

Figure 3-12

Safe Fleet's optimized semi-curved and fold-away pre-production street-side mirror

Drawing courtesy of VTTI

Lessons Learned

The deployment provided an opportunity to learn unique lessons related to mirror configuration development, including current system shortcomings and the challenges of introducing new configurations, as follows:

- Traditional mirror assemblies that include both flat and convex mirrors create significant obstructions to direct forward visibility when mounted below and above the driver window.
- Regarding low mount positions, many NYCT mirror assemblies have been converted to flat glass-only mirrors, and the resulting obstructions are likely among the smallest obstructions due to mirror heads available for transit low-floor bus operations in the U.S.
- A traditional high-mount flat/convex combination with a lower assembly would create similar or worse obstructions for a range of tall bus operators.
- Optimizing street-side mirror indirect and direct visibility obstructions is difficult, based on the requirements for front-axle ground view and two-lane street-side rearward visibility for a 60-ft articulated bus and spotting traffic changing lanes in a 40-ft bus.
- The semi-curved style mirror design provides the best combination of rear and forward visibility performance and accommodates the largest range of visibility performance for short through tall bus operators on 40-ft bus.
- The semi-curved style mirror did not work as well on a 60-ft articulated bus, resulting in a consideration of standardization across fleets vs. tailored performance by bus type.
- It is desirable to map out possible waiver requests, including defining stakeholder/ regulatory agencies ahead of time to avoid delays.
- The NHTSA exemption process takes time and may involve coordination with vehicle manufacturers and other administration or regulatory entities.

Demonstration of Collision Avoidance and Mitigation Technologies on LA Metro Bus Service

Los Angeles County Metropolitan Transportation Authority (LA Metro)

Project Description

The objective of the LA Metro demonstration is to research and evaluate collision avoidance technologies aimed at providing additional protection to pedestrians and cyclists in an urban environment. The evaluation will involve the comparison of data collected on a fleet of transit buses equipped with collision avoidance technologies and operating in similar revenue service environments over an 18-month period. In the original SRD scope of work, LA Metro, in coordination with its research partners, considered five potential solutions, with the goal of identifying two top vendors.

Technology Details

The current vendor, Mobileye, developed the Shield+™ system to visually and audibly alert bus operators of imminent collisions with VRUs using several warnings, including:

- Pedestrian and Cyclist Collision Warning (Mobileye PCW)
- Forward Collision Warning (Mobileye FCW)
- Headway Monitoring Warning (Mobileye HMW)
- Lane Departure Warning (Mobileye LDW)

The bus retrofit solution includes multi-vision smart cameras, three interior displays, and a bus and alert tracking capability that transmits data to the fleet management system. The Shield+™ system also has a "Stealth Mode" that collects regular operations data and logs events (warnings) without displaying visual alerts. This feature allows the project team to set up an experimental design to test system performance and compare operator response by identifying a treatment group (those exposed to visualization of warnings) to a control group (those not exposed to the visualization of warnings) over the course of the evaluation period.

LA Metro also already has a large install base (about 900 buses) of Protran's Safe Turn Alert (STA 1.0) system, which can provide audible exterior audible warnings when the transit vehicle is making a right-hand turn. Although this technology does not meet the collision avoidance capabilities requirements of the SRD program, the project added it for comparison since no procurement or additional funding are necessary to operationalize it.

Progress and Evaluation

FTA conducted a kickoff meeting with the grantees and CUTR in September 2017, and CUTR sent the DCP to LA Metro in March 2019 (the result of the delay in project vendor selection). Appendix G lists the performance measures by evaluation category.

The project team initially selected a second vendor for testing alongside the Mobileye Shield+™ System. During the deployment, the vendor's prototype installation revealed that the technology was not ready for deployment. LA Metro is considering increasing the number of Mobileye units as the sole collision avoidance system per those criteria.

In December 2019, CTE hosted a webinar and presented a preliminary data collection and evaluation plan that lists performance measures and the proposed split of buses to be deployed by technology and mode of operation. The plan proposes to collect data from Mobileye's system conducive to a performance evaluation consistent with CUTR DCP. The project team is currently identifying the bus routes for deployment.

Lessons Learned

The deployment presented challenges due to the current maturity and readiness levels of bus collision avoidance technologies, which provided LA metro with the following lessons learned:

- Technology capabilities and unit costs change as a function of technology maturity, with high uncertainty about levels of readiness and availability. In one instance, a product's functionality did not meet stated performance capabilities. The vendor was working on a next-generation solution to address observed deficiencies, but waiting for product readiness would have caused indefinite delays.
- Collision avoidance technologies for on-road heavy-duty vehicles need further testing to assess their true impact when moving from prototype to implementation in a transit operating environment.
- Quality control and assurance vary greatly by vendor, adding unexpected delays to the deployment schedules. The project team evaluated multiple vendors during the deployment and observed noticeable changes in the market for collision avoidance technologies. Some products have added new capabilities, and others have come down in cost.
- The scope of the collision avoidance market for heavy-duty vehicles is limited, with few vendors offering solutions heavily specialized for other vehicle platforms, such as a focus on preventing backup collisions rather than blind-spot awareness.

- In Mobileye's case, prototype testing revealed quality control issues with new generation parts. These were solved with new parts shipped by the vendor; however, further installations introduced unexpected integration issues, which are currently being addressed.

SECTION 4

Overall SRD Program Evaluation, Initial Observations

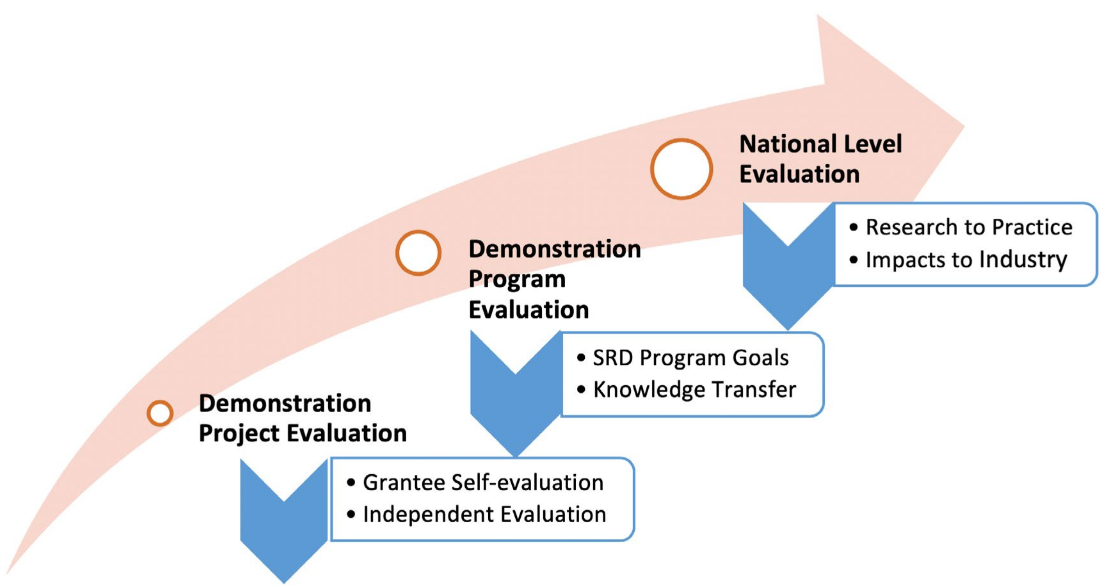
Through the evaluation of each of the SRD Program projects, CUTR developed a set of questionnaires to obtain qualitative assessments of the projects from the grantee perspective. Additionally, CUTR developed questionnaires for the FTA project managers to gain their perspectives on the projects. Both questionnaires were developed with a goal of providing means for a qualitative assessment to discover challenges faced by FTA and grantee project managers and to solicit suggestions for overcoming those challenges for the benefit of future safety research programs. The questionnaires are presented in Appendix H.

SECTION 5

National Level Assessment

Whereas the SRD projects are expected to potentially generate relevant benefits to agencies, the implications of societal benefits of large-scale adoption of research and development pioneering technologies will not be understood unless findings of applicability, benefits, and limitations are broadened beyond the project-level findings from grantees. Once it is ascertained that a technology works, a question about its applicability over a diverse set of conditions and environments still needs to be answered. In other words, "even if we know that this technology works, so what?"

In conformity with FTA's Nested Research Framework, the SRD program national level evaluation will be performed in accordance with the SRD Evaluation Framework presented in Figure 5-1. The goal of the national level evaluation is to build upon the findings from the assessment of the SRD projects to gauge the anticipated impact of the SRD program to the entire industry. It will include a summative evaluation of overall program results based on the data provided by each project grantee. Cost and benefit elements drawn from the project-level evaluations will be scaled to assess the impact of the deployed technologies outside of the deployers' specific contexts. The national-level assessment can be constrained by data availability, the level of maturity of the technologies being deployed, and the grantees' intent to maintain and operate or expand the technology beyond the SRD deployment.



Source: Adapted from FTA Nested Research Framework (April 2018)

Figure 5-1 *SRD Evaluation Framework*

As a component of the project-level evaluations and the combined evaluation of the SRD projects, it is important that any unintended secondary impacts be identified. Managing change, including accounting for unintended consequences, is a challenge that must remain in the forefront as the SRD projects mature to completion. Documentation of the changes that occur (those anticipated as a result of the initial SRD project and those unexpected) as the projects evolve due to technology limitations, data availability, and changes in personnel is a necessary component to managing change.

One aspect of the SRD projects that cannot be overlooked is that the technologies deployed evolve and mature over the progression of the deployments. As manufacturers become aware of the limitations of the technologies, they work to develop new solutions and improvements, which might lead to new innovations altogether. Preliminary evaluations of this product development process indicate that the SRD program is serving as a catalyst for the development of increasingly mature technologies. The SRD program may provide the industry with a better understanding of the limitations of legacy versions of the technology and improvements through innovation.

At a national level, the SRD projects are also providing value added to the industry through increased interagency communication and knowledge transfer. Each SRD project includes a knowledge transfer component that requires the grantees to share the knowledge gained throughout the project through various outlets, such as presentations at conferences. As the knowledge gained is shared throughout the industry, the stakeholder engagements will be detailed and compiled in a table within this evaluation report. The SRD projects have led to improved communication within and among various transit agencies by sharing lessons learned, successes, and challenges.

Appendix A: Project Performance Measures

MTA/Miller Ingenuity, Fixed Location Train Detection and Worker Warning System

Evaluation Category	Evaluation Objective	Measures of Evaluation	Data Source & Collection Frequency
Safety Improvement	Near-miss Events	Number of near-miss events and rate per worker deployment per 1,000 vehicle miles	Flagged events in data log/agency records. Data logs obtained from all WArN Wearables indicating timestamp and GPS location of workers; data logs obtained from all TDMs and TAMs indicating timestamp, GPS location, and speed of train; MTA Sight Distance Chart
	Injuries	Number of injuries and rate of per worker deployment and per 1,000 vehicle miles	Incident/accident reports supplemented with injury reports obtained from agency NTD S&S reporting during demonstration and historically
	Fatalities	Number of fatalities and rate per worker deployment and per 1,000 vehicle miles	Fatality reports obtained from agency NTD S&S reporting during the demonstration and historically
	Stop Over Run	Per grant application evaluation plan	Emergency Stop Device
	Procedural Infraction	Per grant application evaluation plan	MTA Roadway Worker Protection Program
System Effectiveness	System Accuracy	False positive alerts	Timestamp and location of strobe lights emitted from TDMs and TAMs, time-stamped location and speed of LRV, WArN device logs indicating timestamp and worker GPS location; WArN device logs indicating warning timestamp, timestamp and GPS location of worker(s), time-stamped LRV location and speed
		False negative alerts	timestamp and GPS location of TDM and TAM warning strobes, timestamped LRV location and speed, and WArN device logs with employee GPS location and timestamp of alerts
		Train Crew Notification	Wayside Event Recorders
	System Acceptance	Perceptions and acceptance of use by train operators, ROW workers, and other stakeholders	Survey administered at least twice during demonstration period
	System Reliability	Operational Service	Device Recorders and Worker Logs
		Auto Diagnostics	Device Event Recorders
		Maintainability & Ruggedness	Device and Systems Operational Records
Return on Investment	Lifecycle Costs	Unit costs for ZoneGuard system devices and expected life of components; Miller Ingenuity and MTA unit labor costs for installation, configuration, and maintenance of system equipment	Transit agency and vendor records and invoices
	Cost Avoidance	Auto Diagnostics/Avoided Maintenance	Device event recorders
Technology/ Knowledge Transfer	Demonstrations, presentations, webinars, other	Number of outreach events; number and agency/ institution of attendees	Survey instruments administered to webinar and/or demonstration attendees, conference proceedings

NYCT/Metrom Rail, Fixed Location Train Detection and Worker Warning System

Evaluation Category	Evaluation Objective	Measures of Evaluation	Data Source & Collection Frequency
Safety Improvement	Near-miss Events	Number of near-miss events and rate per worker deployment per 1,000 vehicle miles	Flagged events in data log/agency records; Wayside Module generated work zone combined with protocol regarding distance of workers to Individual Wayside Module, train distance to work zone from train UWB modules. Time stamped Train, Wayside, and Personnel Module alarm reports, ranging, and alarm confirmations
	Injuries	Number of injuries and rate per worker deployment and per 1,000 vehicle miles	Injury reports obtained from agency NTD S&S reporting during demonstration and historically
	Fatalities	Number of fatalities and rate per worker deployment and per 1,000 vehicle miles	Fatality reports obtained from agency NTD S&S reporting during demonstration and historically
	Stop Over Run	Per grant application evaluation plan	Emergency Stop Device
	Procedural Infraction	Per grant application evaluation plan	NYCT Track Worker Track Safety Procedure
System Effectiveness	System Accuracy	False positive alerts	Timestamp of UIM alerts and subsequent confirmations, timestamped alarms and confirmations of the workers or work zone; timestamp of PM and/or Individual Wayside Module alert, time-stamped ranging of train and wayside
		False negative alerts	UIM alert timestamp and details including number of workers and confirmations, timestamp of Personnel Module and Individual Wayside Module and their alerts, timestamped train ranging
	System Acceptance	Perceptions and acceptance of use by train operators, ROW workers, and other stakeholders	Survey administered at least twice during demonstration period
	System Reliability	Operational Service	Device recorders and logs
		Auto Diagnostics	Device event recorders
		Maintainability & Ruggedness	Device and systems operational records
Return on Investment	Lifecycle Costs	Detailed unit costs of all components for each module of AURA RWPS along with expected lift of system components, unit labor costs of installation, configuration, and maintenance	NYCT and Metrom Rail records and invoices
	Cost Avoidance	Auto Diagnostics/Avoided Maintenance	Device event recorders
Technology/ Knowledge Transfer	Demonstrations, presentations, webinars, other	Number of outreach events; number and agency/ institution of attendees	Survey instruments administered to webinar and/or demonstration attendees, conference proceedings

WMATA/Protran, Track Inspector Location Awareness with Enhanced Transit Worker Protection

Evaluation Category	Evaluation Objective	Measures of Evaluation	Data Source & Collection Frequency
Safety Improvement	Near-miss Events	Number of near-miss events and rate per worker deployment per 1,000 vehicle miles	Timestamped GPS location of the train and its speed collected via PT-0201, along with PT-0705 wearables providing timestamped GPS locations of all roadway workers, combined with threshold and sight-distance chart; historical and/or control agency records of near-miss events
	Injuries	Number of injuries and rate per worker deployment and per 1,000 vehicle miles	Injury reports obtained from agency NTD S&S reporting during demonstration and historically
	Fatalities	Number of fatalities and rate per worker deployment and per 1,000 vehicle miles	Fatality reports obtained from agency NTD S&S reporting during demonstration and historically
System Effectiveness	System Accuracy	False positive alerts	Location and timestamp of illuminated wayside LEDs collected from PT-0309 and/or back office dispatcher log, combined with location and timestamp of any workers in or around area; 2. alert timestamp and location data collected from PT-0705 combined with timestamped location of any trains and a threshold distance
		False negative alerts	Timestamped train location and speed, PT-0705 device logs with employee GPS location and timestamp, and timestamp of any alerts, including PT-0705 and/or PT-0310 and PT-0309 LEDs
	System Acceptance	Perceptions and acceptance of use by train operators, ROW workers, and other stakeholders	Focus group discussion with employees assigned to use technology.
Return on Investment	Lifecycle Costs	Detailed unit costs of all components for each module in Protran system along with expected life of system components, unit labor costs of installation, configuration, and maintenance along with related project management and support	Protran and WMATA financial records relating to system.
	Cost Avoidance	Oversight of wayside workers	Timestamps of entry and exit of workers on tracks according to data collected from PT-0705
Technology/ Knowledge Transfer	Demonstrations, presentations, webinars, other	Number of outreach events; number and agency/ institution of attendees	Survey instruments administered to attendees at each event

SacRT/Protran, Enhanced Employee Protection Warning System including Roadway Worker Protection

Evaluation Category	Evaluation Objective	Measures of Evaluation	Data Source & Collection Frequency
Safety Improvement	Near-miss Events	Number of near-miss events and rate per worker deployment per 1,000 vehicle miles	RT field forms will be used to track employee reports of near-miss events
	Injuries	Number of injuries and rate per worker deployment and per 1,000 vehicle miles	Injury reports obtained from agency NTD S&S reporting during demonstration and historically dating back 5 years
	Fatalities	Number of fatalities and rate per worker deployment and per 1,000 vehicle miles	Fatality reports obtained from agency NTD S&S reporting during demonstration and historically dating back 5 years
	Work Zone Intrusions	Number of work zone intrusions per 1,000 vehicle miles	Paper-based field forms, or EIC tablet entries, filled out for each use of technologies
System Effectiveness	System Accuracy	False positive alerts	RT will maintain spreadsheet (i.e., Incident Tracker) that tracks entries of all identified false positive alerts. Data will be entered manually using responses from employee survey after each shift that technology was used. Also will include description of reasons waiver required to be obtained for downtown area.
		False negative alerts	Spreadsheet that tracks entries of all identified false negative alerts will be maintained by RT (i.e., Incident Tracker). Data for spreadsheet will be entered manually using responses from employee survey after each shift that technology was used.
	System Acceptance	Perceptions and acceptance of use by train operators, ROW workers, and other stakeholders	Surveys developed to garner system acceptance from perspective of each user type
Return on Investment	Lifecycle Costs	Detailed unit costs of all components for each module in Protran system along with expected life of system components, unit labor costs of installation, configuration, and maintenance	Protran and RT records relating to system deployment
	Cost Avoidance	Oversight of wayside workers	Details of cost savings, including soft costs such as reduced time necessary to complete audit, improved training efficiency, reduced labor hours due to increased efficiency in work zone establishment, and any other numerical or anecdotal costs that demonstrate value of systems
Technology/ Knowledge Transfer	Demonstrations, presentations, webinars, other	Number of outreach events; number and agency/ institution of attendees	Survey instruments administered to attendees at each event

CTA, Operations Control Center Safety Enhancements Project

Evaluation Category	Evaluation Objective	Measures of Evaluation	Data Source & Collection Frequency
Safety Improvement	Near-miss Events	Number of near-miss events and rate per worker deployment per 1,000 vehicle miles	Local event recorders; CC logs collected during demonstration and historically
	Injuries	Number of injuries and rate per worker deployment and per 1,000 vehicle miles	Injury reports obtained from agency NTD S&S reporting during demonstration and historically
	Fatalities	Number of fatalities and rate per worker deployment and per 1,000 vehicle miles	Fatality reports obtained from agency NTD S&S reporting during demonstration and historically
	Red Signal Violations	Number of red signal violations per line and by vehicle mile traveled	SCADA data/CC logs denoting events pre- and post- system deployments
Safety Effectiveness	System Accuracy	False positive WA alerts	WA activation logs compared to worker call-on logs
Return on Investment	Lifecycle Costs	Detailed unit costs of any hardware, along with expected lifecycle, unit labor costs of installation, configuration, and maintenance	CTA and/or QEI/QuicTrac
	Cost Avoidance	Improved efficiency detecting loss of shunt and loss of traction power	Historical and demonstration-period records of maintenance and labor charges related to identifying loss of shunt and loss of traction power issues
Technology/ Knowledge Transfer	Demonstrations, presentations, webinars, other outreach events	Number of outreach events; number and agency/ institution of attendees	Survey instruments administered to attendees at each event

Pierce Transit, Bus Collision Avoidance and Mitigation

Evaluation Category	Evaluation Objective	Measures of Evaluation	Data Source & Collection Frequency
Safety Improvement	Near-miss Events	Number of near-miss events and rate per 1,000 vehicle miles	From CAD/AVL, collect identifying information and trip details to identify control/treated and for computing rates: Bus Number, Bus Route ID, Trip ID Code, Trip Start Time, Strip Stop Time, Trip Mileage, Operator ID Code, Telematics GPS providing the longitude/latitude coordinates of the vehicle. From PASS Logger, collect information used to identify PASS Events/ "near-miss" events triggered by high g-forces detected: Bus Number (for linking, PASS Event ID, PASS Event Window Indicator, Vehicle Location/GPS coordinate of a PASS Event; Timestamp of PASS Event; PASS Operating Mode; for further analysis, CAWS Collision Warning: Object Distance; TTC
	Collisions	Number of collisions and rate per 1,000 vehicle miles	Collision reports from agency records during demonstration.
			WSTIP historical records of collision claims categorized and analyzed by Veritas Forensic Accounting & Economics
	Injuries	Number of injuries and rate per 1,000 vehicle miles	Injury reports obtained from agency NTD S&S reporting during demonstration
			WSTIP historical records of personal injury claims categorized and analyzed by Veritas
	Fatalities	Number of fatalities and rate per 1,000 vehicle miles	Fatality reports obtained from agency NTD S&S reporting during demonstration
			WSTIP historical records of fatality claims categorized and analyzed by Veritas
Safety Effectiveness	System Accuracy	False positive warnings, False negative warnings	Incidence of false positives and false negatives by route and driver provided by transit event logging system (TELS) installed on four buses and analyzed using UW developed single board computers e.g. Jetson); linked with Bus Telematics Unit Number/Bus Number
	System Performance	Stopping distance and effect on bus passengers	Stopping distance and real-time g-force deceleration monitoring results reported by VTTI and associated passenger motion profiles
Return on Investment	Lifecycle Costs	Itemized cost per unit for system equipment, configuration, and installation	DCS records and invoices
		Maintenance costs	Maintenance trouble tickets developed by vendors and reported during driver checks and inspections
		Expected life of system components	DCS
	Cost Avoidance	Gross cost of insurance claims paid for personal injury and property loss related to CAWS- and CAWS+AEB -avoidable/ -mitigated incidents	WSTIP historical claims records categorized and analyzed by Veritas
			Document describing methodology to estimate reductions in claims, cost-savings, and benefit/ cost ratios projected for installation of CAWS and CAWS/AEB at Pierce Transit
		Costs related to CAWS- and CAWS+AEB -avoidable/-mitigated incidents not reimbursed by insurance	Financial records of any internal expenses incurred as result of property loss or personal injury not covered by insurance
Technology/ Knowledge Transfer	Demonstrations, Presentations, Webinars, Other	Number of outreach events; number and agency/institution of attendees	Survey instruments administered to attendees at each event

NYCT, Transit Bus Mirror Configuration Safety Research and Development

Evaluation Category	Evaluation Objective	Measures of Evaluation	Data Source & Collection Frequency
Safety Improvement	Near-miss Events	Number of near-miss events and rate per 1,000 vehicle miles	Bus operator reports of visibility-related near-miss events, linked to data on bus operator, bus, bus route, time, and location; collected for pre- and post- mirror solution set(s) sample and control sample
	Collisions	Number of collisions and rate per 1,000 vehicle miles	Collision reports from agency records during demonstration collected for pre- and post-mirror solution set(s) sample and control sample
	Injuries	Number of injuries and rate per 1,000 vehicle miles	Injury reports obtained from agency NTD S&S reporting during demonstration
	Fatalities	Number of fatalities and rate per 1,000 vehicle miles	Fatality reports obtained from agency NTD S&S reporting during demonstration
Safety Effectiveness	System Acceptance	Perceptions and acceptance of use by bus operators	VTTI output from weekly operator self-report surveys
Return on Investment	Lifecycle Costs	Itemized cost per unit for system equipment, configuration, and installation	New Flyer, Safe Fleet, and Recaro Seating records and invoices
		Maintenance costs	Maintenance trouble tickets related to mirror assembly reported during driver checks and inspections
		Expected life of system components	New Flyer, Safe Fleet, and Recaro Seating
	Cost Avoidance	Gross cost of insurance claims paid for personal injury and property loss related to visibility-related incidents	Categorized claims records for treated and control samples collected during demonstration
		Costs related to visibility-related incidents not reimbursed by insurance	Financial records of any internal expenses incurred as result of visibility-related property loss or personal injury not covered by insurance
Technology/ Knowledge Transfer	Demonstrations, Presentations, Webinars, Other	Number of outreach events; number and agency/ institution of attendees	Survey instruments administered to attendees at each event

LA Metro, Demonstration of Collision Avoidance and Mitigation Technologies on LA Metro Bus Service

Evaluation Category	Evaluation Objective	Measures of Evaluation	Data Source & Collection Frequency
Safety Improvement	Near-miss Events	Number of near-miss events and rate per 1,000 vehicle miles	Timestamped Mobileye Shield+ alerts and Protran STA System proximity-sensor alerts linked to bus operator, bus, and route identifiers; field reports and right-side Protran alerts for control buses
	Collisions	Number of collisions and rate per 1,000 vehicle miles	Collision reports from agency records during demonstration linked with information on bus identification and vehicle miles, driver identification, route identification, and time
	Injuries	Number of injuries and rate per 1,000 vehicle miles	Injury reports obtained from agency NTD S&S reporting during demonstration linked with information on bus identification and vehicle miles, driver identification, route identification, and time
	Fatalities	Number of fatalities and rate per 1,000 vehicle miles	Fatality reports obtained from agency NTD S&S reporting during demonstration linked with information on bus identification and vehicle miles, driver identification, route identification, and time
Safety Effectiveness	System Accuracy	False positive warnings, False negative warnings	Bus operator field reports identifying FP and FN
	System Acceptance	Perceptions and acceptance of use by bus operators	Operator self-report survey of system activity, trust ratings, route type
Return on Investment	Lifecycle Costs	Itemized cost per unit for system equipment, configuration, and installation	Mobileye, Protran, and agency records and invoices
		Maintenance costs	Maintenance trouble tickets developed by vendors and reported during driver checks and inspections
		Expected life of system components	Mobileye and Protran
		Agency/internal costs related to technology-avoidable/-mitigated incidents not reimbursed by insurance	Financial records of any internal expenses incurred as result of property loss or personal injury not covered by insurance
Technology/ Knowledge Transfer	Demonstrations, Presentations, Webinars, Other	Number of outreach events; number and agency/ institution of attendees	Survey instruments administered to attendees at each event

APPENDIX

B

Qualitative Data Collection: Interview Questionnaires

SRD Close-Out Interview Guide – FTA Grantee

Purpose: The purpose of this interview and the responses you provide are to improve TRI's safety research demonstration program grant solicitation, award, and management processes to assist FTA by providing the data necessary to perform a qualitative assessment of the project successes. Information provided will be summarized in a TRI internal document that will be used to inform process and overall safety research demonstration program improvements. We would like to learn about and understand any challenges you may have faced through each phase of the project, from initial proposal development through the close of the project. In addition, we would like to collect your feedback on the ways in which those challenges can be reconciled, and the safety research demonstration process can be improved.

This interview includes a series of questions associated with the following phases of the project:

- Notice of Funding Opportunity (NOFO) Solicitation
- Proposal Preparation and Submittal
- Project Award and Grant Acceptance
- Grant Amendments/Modifications
- FTA Communication
- Progress Reporting and Invoicing
- Final Report
- Performance Measures and Data Collection
- Overall Project Observations

Name of Project: ______________________________

Grantee: ______________________________

Grantee Project Manager/Interviewee: ______________________________

I. NOFO Solicitation

1. Were you involved in the NOFO solicitation response preparation? If no, skip to Question 9.
2. How were you made aware of the NOFO?
3. Did the NOFO clearly define the intent of the solicitation and the description of theme areas sufficiently?
4. Did the solicitation process allow sufficient time to develop proposals, secure vendors or other partners, and solidify local participation?
5. In general terms, rate the clarity/thoroughness of proposal requirements, submittal process, evaluation criteria, and selection process from 1 to 5, with 1 reflecting a lack of clarity and a 5 indicating that the process was seamless and well understood. Please provide additional discussion of any scores of 3 or less.
6. Did you feel that there could have been/should have been more guidance provided in the NOFO?
7. Did you know that you could have contacted FTA for clarification?

8. What areas could FTA have provided better guidance if they could have asked?
9. If you were not involved in the NOFO solicitation response, at what phase in the project did you become involved?
10. Do you have any recommendations to improve the structure of the SRD Program?
11. Are there any other difficulties or process-related improvement topics you would like to share related to the NOFO solicitation and associated process?

II. Proposal Preparation and Submittal

1. Were you involved in the proposal preparation and submittal process? If not, skip to Section III.
2. Were the proposal requirements and evaluation criteria clearly identified?
3. Was there sufficient guidance provided, including FTA's evaluation criteria, to assist you in the preparation of a responsive proposal?
4. Did you experience any difficulties in meeting the requirements for documentation/ justification and the write up in the application?
5. Was there enough guidance provided on the development of your line item budget or match requirements? Did you have any difficulty securing or identifying sources or cash or in-kind match?
6. Did you encounter any difficulties electronically submitting your proposal?
7. Did you have to request any exceptions or waivers to FTA requirements or policies necessary to implement the proposed project successfully?
8. Are there any other difficulties or process-related improvement topics you would like to share related to Proposal Preparation and Submittal?

III. Project Award and Grant Acceptance

1. Is there anything FTA asked you to include in the scope of work that did not make sense for which clarification was required? If yes, please discuss.
2. Would a scope of work template have been a useful tool in the creation of your final scope?
3. List any major differences between the initial application and the final scope of work that was developed for the project?
4. Where there any delays in submitting the required documents and executing the final cooperative agreement in TrAMS? If so, what were the specific issues or sources of?
5. How long did the process take from initial notification of grant award to completing the FTA contracting process? Were you able to sign agreements with your project partners prior to FTA grant award? Were there obstacles that prevented this pre-FTA award action? Did you sign contracts with your project partners after grant award? How long did that process take? Were you unable to sign contracts with any of your original vendors or project partners? If yes, what prevented you from contracting with the partner?
6. Did the amount of time between the initial notification of grant award to completing the contracting process have any effect on your project? If yes, please describe.
7. Are there any other difficulties or process-related improvement topics you would like to share related to Project Award and Grant Acceptance?

IV. Grant Amendments/Modifications

1. Were you the original manager for this project at grant award? Or, were you transitioned into this role during the demonstration? Do you have any recommendations to FTA on how to make these transitions easier?
2. On this project, did you submit any scope or budget modifications? If no, skip to the next section.
3. If yes, were any of these a result of changes to the vendor(s) or other project partners participating in the demonstration? Please explain.
4. Were any of these changes associated with project delays? What type of delay occurred that required a schedule modification (i.e., delays in initial testing due to weather, equipment failures or defects, software/hardware troubleshooting, or other delay)?
5. What could FTA have done to minimize delays and/or project modifications?
6. Were there any difficulties in submitting the requested modification in TrAMS? If so, what were those issues?
7. Are there any other difficulties or process-related improvement topics you would like to share related to Grant Amendments/Modifications?

V. FTA Communication

1. On a scale from 1 to 5, with 1 being little correspondence/responsiveness and 5 being very responsive, how would you rate FTA's communication throughout the all project phases in which you were involved?
2. Did FTA participate in regularly scheduled progress meetings?
3. Did you feel comfortable consulting with FTA on issues with vendors, budget, delays, or other project challenges?
4. On a scale from 1 to 5, with 1 being unsupportive or disengaged and 5 being very supportive and engaged, how would you rate FTA project management?
5. Do you have any recommendations on how communication can improve between grantees and FTA?
6. Are there any other difficulties or process-related improvement topics you would like to share related to FTA communication?

VI. Progress Reporting and Invoicing

1. Do you think the quarterly progress reporting frequency is too lenient, adequate, or too strict?
2. Did FTA provide a progress report template or other guidance to you to assist in developing your quarterly progress reports? If not, would a template have been useful?
3. Reflecting on the progress reports submitted to FTA and the contents of those reports, are there certain elements that you feel should be included in any future FTA progress report templates or guidance?
4. Did you submit progress reports in TrAMS? If so, did you experience any difficulties?
5. Did you include data collection updates in your progress reports?
6. Did progress reports sufficiently describe your progress in meeting the performance measures established for the project?

7. Did progress reports sufficiently address the project timeline established in the scope of work and provide justification for any delays?
8. Did you provide a description of any existing or anticipated delays or other unexpected issues with meeting the project schedule?
9. Did you find the Delphi invoicing process easy to understand?
10. Did you have any difficulties submitting invoices or receiving payment? If yes, please describe.
11. At what frequency did you submit invoices? (e.g., quarterly, semi-annually, annually)
12. Did you receive payments in a timely manner?
13. Are there process improvements that FTA could implement that would smooth progress reporting/invoicing?
14. Are there any other difficulties or process-related improvement topics you would like to share related to Progress Reporting and Invoicing?

VII. Final Report

1. Did you find FTA final report guidance sufficient?
2. Did the 90-day submittal deadline provide sufficient time for you to effectively prepare and submit the final report?
3. Would a 2-year interim report have helped you overcome any difficulties you may have experienced in the development of the final report?
4. Did FTA review and provide comments on the final report in a timely manner? Did you find this feedback valuable?
5. Once the final report was submitted and forward for FTA publication, were you required to make any additional edits? Can you provide any observations on your experience with FTA's publication process?
6. Are there any other difficulties or process-related improvement topics you would like to share related to the Final Report development, submittal, and publication process?

VIII. Performance Measures and Data Collection

1. FTA requires SRD grantees to track the following performance measures for associated projects: system effectiveness, safety improvement, and return on investment. Did these performance measures align with your demonstration project?
2. Are there other performance measures that FTA should consider requiring for future SRD projects?
3. Were the data elements associated with the original performance measure descriptions and data collection plan, available as intended?
4. Were there limitations to the type of data available? If yes, please describe.
5. Were there any data access limitations or challenges with your technology vendor? If yes, please describe.
6. Were there anticipated data elements included in the original statement of work and/or data collection plan that could not be retrieved (or were not captured) by the vendor(s), your organization, or other partners? If yes, please describe.

7. Did the Data Collection Plan assist you in organizing and effectively performing your data collection and analysis processes?
8. Would it have been beneficial to have a Data Collection Plan template available to you early in the process?
9. Discuss the greatest challenges you experience in the identification and/or modification of your performance measures and the data that was available to you to track those measures.

IX. Overall Project Observations

1. Level of Success – on a scale from 1 to 5, with 1 being not successful and 5 very successful, please rate the overall success of this project
2. Level of Success - Qualitative Statement: Can you make a statement to the success of this project overall? Discuss the success of the project – what made it successful. Or, discuss the reasons why it may not have been successful, in your opinion.
3. Degree to Which Performance Measures were Met: When reflecting on the performance measures and associated metrics established for this project, to what degree would you say this demonstration project met each of the following performance measures. Please rate on a scale from 1 to 5, with 1 indicating the project did not meet the associated performance measure and a 5 indicating that it fully met the performance measures and associated metrics.
    a. System Effectiveness
    b. Safety Improvements
    c. Return on Investment
4. Benefits of the Project: Would you say the outcome and lessons learned from this project will benefit the industry, demonstrating the utility of the technology or processes established to reduce transit safety risk and mitigate areas of concern?
5. Knowledge Transfer: Were you able to meet the knowledge transfer requirements of this research demonstration project, including your participation/presentations in conferences, workshops, web-conferences, webinars, industry events, or other activities?
6. Technology "readiness": When reflecting on your original proposal and the demonstration phase, did you find the "readiness" of the technology as expected or not as "ready" as expected?
7. Is this technology now readily available on the marketplace?
8. Do you plan to test another system/technology?
9. Did you purchase additional units or continue the testing system-wide? If budget is available, do you plan to purchase this technology and deploy system-wide?

SRD Close-Out Interview Guide – FTA Project Managers

Purpose: The purpose of this interview and the responses you provide is to improve TRI's research demonstration program. Information provided will be summarized into a TRI internal document that will be used to inform process and overall safety research demonstration program improvements. Specifically, we are trying to learn about and understand some of the challenges faced by TRI project managers in each of the phases of the projects. In addition, we would like to collect your feedback on what might be done to mitigate and/or prevent those issues in the future, and overall process improvement.

Name of Project: ______________________________

Grantee: ______________________________

Project Final Report Release Date: ______________________________

FTA Project Manager: ______________________________

I. Items/Processes Defined as "Major"

1. Through the processes established for TRI sponsored research demonstration projects, do you have any specific areas of concern that you would define as "major," indicating a need for process improvement?
2. Do you have any thoughts on how that/those processes could be improved?
3. Through the execution of the demonstration project, do you have any specific areas of concern that you would define as major, indicating something that should be addressed during the proposal review process, consideration during the project selection process, or a part of the agreement with the grantee?

II. Pre-Award Phase

1. Did you participate in the solicitation proposal review process? (In no, skip to Section III).

Solicitation

1. In your opinion, did the solicitation process allow sufficient time for proposals to be developed, teaming with a vendor to be secured, and local participation to be identified?
2. Was there an opportunity for pre-proposal engagement with potential applicants?
3. Turning to the actual solicitation document/Notice of Funding Opportunity, are there areas of improvement that could/should be made in the flow, identification of need for demonstration projects based on areas of risk, content, description of performance measures, proposal evaluation criteria, selection process, or elements?

Proposal Review and Selection Process

1. Did original NOFO sufficiently describe the selection criteria that would be used by TRI to evaluate proposals?
2. Were the selection criteria described in sufficient detail to allow you to effectively complete proposal reviews?

3. During proposal review, did you feel that potential awardees understood the selection criteria established for the project?
4. Was project scoring criteria/process made clear to you as an evaluator?
5. In general terms, rate the proposal review and selection process from 1 to 5, with 1 reflecting a lack of clarity in the criteria established for proposal review and selection and a 5 indicating that the process was seamless and well understood. Please provide additional discussion of any scores of 3 or less.
6. Now that the demonstration project has concluded, are there any additional criteria that should be considered in proposal development, review, and selection?
7. Turning now to project selection, in your opinion, were there a sufficient number of responsive proposals submitted and evaluated? If not, please discuss. What could have been done to ensure a better response?
8. Was the final scoring method understood (were weighting criteria and method for calculation understood at the beginning of the proposal review and scoring process)?
9. Based on your experience, do you have any recommended process improvements?

Award Process

1. Once the grantee selection process concluded, can you identify any issues associated with the timeliness or "completeness" of final statements of work (clearly stated deliverables, performance measures and specific metrics in the table format, required vendor documentation, or other documents)?
2. Were there contractual elements that required extensive engagement with vendors on the project team (meaning, were there issues with vendor proprietary, data release, or personnel information that created difficulties for the primary grantee)?
3. Turning specifically to contracting, were there any delays or difficulties working with the grantee to submit required documents and execute the final agreement in TrAMS?
4. Were there any internal delays in executing the agreement with the grantee?
5. Are there any areas of improvement you would like to identify related to the award process?

III. Project Management Phase

Performance Monitoring/Progress Reports

1. Did this project include a third-party independent evaluator (if applicable)?
2. Did progress reports sufficiently describe the grantee and vendor's progress in meeting the performance measures established for the project?
3. Was a data collection plan developed for the project?
4. Were there any modifications made to that plan based on vendor capabilities/willingness or other factors?
5. Did progress reports sufficiently address the project timeline established in the scope of work and provide justification for any delays?
6. Did the grantee submit progress reports in a timely manner?

7. Did the grantee identify any issues related to data collection and their ability to produce data outputs in accordance with their data collection plan?
8. Now that this project has concluded, can you identify any areas of improvement for consideration in subsequent safety research demonstration projects?

Progress Meetings

1. Did grantees establish regularly scheduled progress meetings for the project team? Were you invited to those progress meetings?
2. Did the grantees provide a summary of those meetings to you following each meeting?
3. Were any areas of follow-up effectively addressed at subsequent progress meetings?
4. Were all parties represented in the progress meetings – grantee, technology vendor (where appropriate), and other agency personnel?
5. Are there progress meeting and/or progress reporting methods that should be standardized? Or, is there value in project managers having the opportunity to define their own project management/administrative requirements for grantees?

Communication with Grantee(s)

1. On a scale from 1 to 5, with 1 being little correspondence/responsiveness and 5 being very responsive, how would you rate the grantee?
2. Were there any communication issues that should be addressed specifically in future solicitations and contracting activities?
3. For future TRI projects (and project managers), would you have any advice on communication practices that you found helpful?

Scope/Budget Modifications

1. On this project, did the grantee submit any scope or budget modifications?
2. If yes, were any of these change a result of changes to the vendor participating in the demonstration (or a change in vendors)?
3. Were any of these changes associated with project delays? What type of delay occurred that required a schedule modification (i.e., delays in initial testing due to weather, equipment failures or defects, software/hardware troubleshooting, or other delay)?
4. What would you identify as the most common reasons for scope modifications? Are there methods or measures that could be taken during the initiation of the project to reduce scope changes/project amendments?

Project Scheduling

1. Other than those issues currently mentioned, were there additional project scheduling concerns that you had with this project?
2. Did grantees seem to understand the complexity of undertaking a demonstration project with a vendor when they developed the initial project schedule (i.e. time to negotiate and finalize vendor agreements, length of time to take delivery of technology, time for sufficient testing prior to full deployment, process and time that it takes to troubleshoot, other delays outside the agency or vendor's control, etc.)?

Invoicing

1. What would you define as the minimum elements that should be required with the grantee progress reports/billings?
2. Did grantee invoice in accordance with an agreed upon schedule (project schedule/milestones)?
3. Was the grantee able to successfully invoice via Delphi?
4. Were there any processing issues for either the grantee or FTA in ECHO?
5. Are there any areas for improvement associated with the invoicing process?
6. Should there be requirements established for invoice scheduling (e.g., quarterly, semi-annually, annually)

Reporting – Interim/Final

1. Did the grantee submit an interim report in a timely manner?
2. Did that report include the success of the demonstration project in meeting the established performance measures with associated metrics?
3. Did the grantee submit the final report in a timely manner?
4. Did the report include the success of the project in meeting the established performance measures?
5. Did it include qualitative or quantitative data on the usefulness, transferability, or overall benefit of the project for the transit industry?
6. Did it sufficiently address knowledge transfer activities? Were knowledge transfer activity expectations met?
7. Are there areas of improvement in the process of developing, submitting, and final review and approval of interim or final reports that you would like to share?

Grant Closeout

1. How would you characterize the grant closeout process – both for you as the project manager and for the grantee?
2. Are there activities associated with grant closeout that could be streamlined or otherwise improved?
3. What would you say is the most challenging aspect of grant closeouts?
4. Would you have any recommendations for process improvements that might address this/these aspect(s)?

IV. Overall Observations

1. Level of Success – Qualitative Statement: Can you make a statement to the success of this project overall?
2. Degree to Which Performance Measures were Met: When reflecting on the performance measures and associated metrics established for this project, to what degree would you say this demonstration project met each of those performance measures.
3. Benefits of the Project: Would you say this project will benefit the industry, demonstrating the utility of the technology or processes established to reduce transit safety risk and mitigate areas of concern for the industry?

4. Knowledge Transfer: Did the grantee meet expectations regarding knowledge transfer, including participation/presentations in conferences, workshops, web-conferences, webinars, industry events, or other activities?
5. Grantee Cooperation and Overall Project Management: Do you have any observations about the cooperation and communication with the grantee?
6. Please name four areas for which process improvements could be made.

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