TRANSIT ADVISORY COMMITTEE FOR SAFETY (TRACS)

2018-2020 Charter

Roadway Worker Protection Final Report

Contents

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Introduction: 2018-2020 TRACS Charter Tasking and Executive Summary

FTA's Tasking to TRACS and Overview of the Safety Focus Areas

The United States Department of Transportation's (USDOT) Federal Transit Administration (FTA) encourages implementation of measures that will strengthen safety culture at every level of the transit industry and improve safety through modernization. Since its founding in 2009, the Transit Advisory Committee for Safety (TRACS) has supported FTA in this effort by providing information, advice, and recommendations on transit safety.

Under the 2018-2020 TRACS Charter, FTA tasked TRACS to "review emerging technologies and recommend public transportation innovations in safety that FTA can implement in support of the public transportation sector." To assist the transit industry's shift towards the principles of Safety Management Systems (SMS), FTA encouraged the Committee to make recommendations using an SMS framework. Additionally, FTA tasked TRACS to identify and prioritize technology evaluation criteria. A summary of TRACS conferences is provided herein as Appendix A-1. TRACS has worked continuously since its inception, except for the two-year period, 2016 to 2018.[1]

To support the 2018-2020 Charter, TRACS members formed three subcommittees focused on the following safety focus areas: 1) Trespass and Suicide Prevention (TSP), 2) Employee Safety Reporting (ESR), and 3) Roadway Worker Protection (RWP). The FTA selected and assigned the safety focus area, TSP, to the Committee. The FTA also requested that TRACS select two additional safety focus areas, so the Committee selected RWP and ESR because of their importance to ensuring transit safety. While FTA and TRACS has previously proposed advisories and recommendations on RWP and ESR, respectively,[2] the recommendations under the 2018-2020 Charter will specifically address these safety focus areas through the lens of emerging technologies and innovative processes. Previous TRACS reports and recommendations can be found in the TRACS Archive.

Executive Summary

Overview and Recommendation Summary

In response to a series of industry accidents and two urgent recommendations from the National Transportation Safety Board (NTSB),[3] FTA issued Safety Advisory 14-1 to provide

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[1] No charter or committee was established for this time period. TRACS consequently did not convene nor meet or otherwise conduct any activity.

[2] Federal Transit Administration. (2013). *Safety Advisory 14-1: Right-of-Way Worker Protection*. https://www.transit.dot.gov/oversight-policy-areas/safety-advisory-14-1-right-way-worker-protection-december-2013#:~:text=Regulations%20%26%20Guidance-,Safety%20Advisory%2014%2D1%3A%20Right%2Dof%2D,Way%20Worker%20Protection%20December%202013&text=DOT%20is%20committed%20to%20ensuring,persons%20who%20have%20a%20disability. TRACS reports and recommendations can be accessed through the TRACS Archive.

[3] *See* NTSB Recommendations R-13-039 and R-13-040 for more information.

guidance to State Safety Oversight Agencies (SSOAs) and rail-fixed guideway public transportation agencies on redundant protections for roadway workers in the rail transit industry. The advisory also required that these organizations review and revise rules and procedures that protect roadway workers from trains and moving equipment.[4] A comprehensive RWP program protects employees who perform on-track work or maintenance from the many dangers of working while on the right-of-way.

The two urgent safety recommendations that NTSB issued to FTA in 2013 followed the death of two Bay Area Rapid Transit (BART) employees.[5] These employees were granted access to the railway by notifying the agency's operations control center of their presence. No other protections were in place to ensure train-to-worker separation to protect trackworkers from fouling the trackway area at the same time as trains are operating. The first NTSB recommendation endorsed the need for all transit agencies to require and provide redundant protections for roadway workers. Redundant protections could include the use of positive train control, secondary warning devices, or shunting devices on tracks. The second NTSB recommendation called for rail transit agencies (RTAs) to review their rules and procedures for roadway workers and revise them to eliminate any authorization that allows workers to access transit rights-of-way in which the workers are dependent solely upon themselves to provide protection from trains and moving equipment. [6]

Recognizing the priority that FTA and NTSB have placed on RWP, the Committee chose this as a safety focus area. Through the exploration of multiple technology services and vendors, the Committee planned to develop a comprehensive understanding of what transit agencies are using to comply with Safety Advisory 14-1 and institute stronger RWP programs. Notably, the Transportation Technology Center Inc. (TTCI), in coordination with the American Public Transportation Association (APTA), issued a survey to 35 transit agencies to collect a sample of the rules, practices, procedures, and technologies that agencies are currently using.[7] Additionally, the Committee set out to further its own understanding of the human factors-component and the role behavior-based interventions, such as behavior-based safety (BBS), can play in understanding and improving RWP rules, practices, procedures, and use of safety technologies.[8]

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[4] Federal Transit Administration. (2013). *op cit.*

[5] *See also* NTSB Accident Report that led to R-13-39 and R-13-40; https://www.ntsb.gov/investigations/AccidentReports/Reports/RAB1503.pdf.

[6] Federal Transit Administration. (2013). *Safety Advisory 14-1: Right-of-Way Worker Protection*. *op cit*.

[7] The TTCI report was not ready for publication at the time that this TRACS report had to be completed. TRACS has been informed that TTCI's report should be available in 2021. TTCI is a wholly owned subsidiary of the Association of American Railroads. See https://www.ttci.tech/

[8] *See* Geller, E. Scott. (1996) *The psychology of safety: How to improve behaviors and attitudes on the job*. Radnor, PA, Chilton Book Co, *see also* Perdue, Sherry R. (2000, June 25-28). *Beyond observation and feedback: Integrating behavior safety principles into other safety management systems*. Presented at the American Society of Safety Engineers (ASSE) Professional Development Conference and Exposition, Orlando Florida.

As subject matter experts have developed a stronger understanding of roadway worker accidents and fatalities, new technologies have emerged that focus on protecting roadway workers and integrating their worktimes and workload with revenue and non-revenue on-track movements. The integration of these existing work processes and technology and integrating them within operational and maintenance environments will not only benefit roadway worker safety, but will also benefit overall safety for the transit-riding public due to better maintenance practices. RWP practices can break down due to service pressures, but the Committee wants to emphasize that this should not come at the expense of the safety of workers. Additionally, the improvement of technologies over time has the potential to improve train control systems (e.g., positive train control systems).

It is clear that RWP is of great importance to the transit industry and the public due to the special responsibilities and increased risks to roadway workers. While the general public is prohibited from occupying tracks and rights-of-way, roadway workers are required to be on the tracks, even during revenue and non-revenue operations, while the trains are operating. Due to the nature of the work, roadway work has been identified in fatality statistics as a high-risk occupation and has been the subject of many NTSB reports.

The TRACS Committee recommends that FTA ensure that RTAs implement innovative new safety technology for roadway worker protection in the form of secondary warning systems, to give advance notice to roadway workers and train operators of approaching trains and workers on the tracks. These systems must be secondary systems in that they should not be solely relied upon, but provide redundancy to essential primary protections such as communication between dispatcher/controllers, train operators, and roadway workers; signals; work orders and work zones; train-stop technology; watchpersons and flaggers; propulsion power downtime, and train control systems such as automatic train control or positive train control.

In summary, TRACS makes the following recommendations:

1) Require Use of Secondary Warning Systems
2) Funding for New Research and Implementation of New Systems and Technology
3) Minimum RWP Safety Requirements as the Basis for Secondary Warning Systems
4) Develop RWP Safety Technology Reliability Criteria
5) Development of Risk-Based Safety Metrics Including Leading Indicators
6) Fatigue Management for Maintenance, Controller, and other Non-Operating Personnel
7) Research and Create Guidance on Cognitive Workload and Distraction of LRT Operators Using In-Cab RWP Technology
8) Behavior-Based Safety Systems for RWP

FTA should continue work to fill in the information gaps listed in these recommendations. Given the economy-of-scale research that the FTA is in a position to conduct, rather than the various

SSOAs attempting to each do the necessary research, the FTA should address these gaps, especially the issue of not only what might be impeding the utilization of redundant protections, but also the issue of what might be impeding the comprehensive utilization of robust primary protections on all relevant RTAs. To accomplish this, as well as any new task, when the FTA reconvenes TRACS under the next two-year charter, it should provide TRACS with the resources that historically have been necessary to provide quality and comprehensive reports.

Statement Regarding the 2018 - 2020 TRACS Charter

The lack of resources available to the current TRACS, including reducing the membership by half relative to previous committees, and the loss of Volpe's assistance and expertise,[9] have left the current TRACS with insufficient capacity to create a report of the same completeness, quality, and professionalism as reports under previous charters. Additionally, the current TRACS was given three tasks to complete, in contrast to the two tasks usually given to the previous committees. Further, TRACS was given an additional task, establishing technology evaluation criteria,[10] which was particularly relevant to the RWP task where emerging technologies cannot be evaluated on the basis of casualty history, i.e., lagging indicators. The RWP subcommittee had to accomplish an elaboration of the *potential impact to safety* in order to more adequately address the research on leading indicators, not just lagging indicators.

Notably also, with such reduced resources, TRACS had no reserve capacity to address further loss of members' time when the COVID-19 pandemic and nationwide social unrest ensued. With this in mind, TRACS considers this report to still have value, both in the information that it contains, and in the identification of information gaps that should be recognized and addressed.

[9] Notably, relevant to these recommendations, especially recommendation #7, and central to the overarching theme of technological innovations in rail safety, the Volpe National Transportation Systems Center (the Volpe Center) operates the FRA's Cab Technology Integration Laboratory (CTIL). See US Department of Transportation, Federal Railroad Administration (2020). *Cab Technology Integration Laboratory (CTIL) Overview*. Washington, DC: USDOT, FRA. https://railroads.dot.gov/CTIL This resource was not available to TRACS.

[10] See FTA PowerPoint presentation at the February 25, 2020, TRACS meeting, pg. 7. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-programs/safety/147771/tracs-fta-presentation-february-2020.pdf

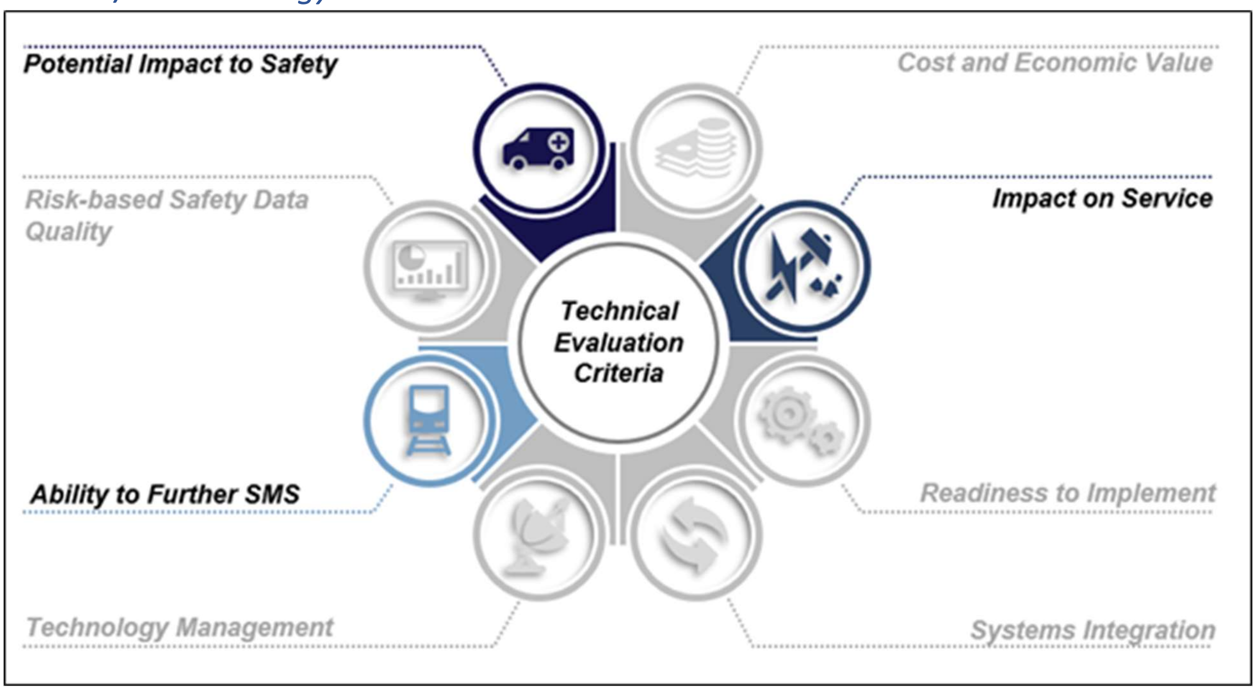
Recommendations

RWP Recommendation #1 – Require Use of Secondary Warning Systems

Recommendation

The Committee recommends that FTA require secondary warning systems for mainline operations or at high-risk locations. The Committee recommends that FTA create a resource document that identifies existing secondary warning systems, and describes their primary features, their maturity, test experience, implementation readiness, implementation experience, necessary hardware, and installation work needed. Such descriptions should include warning-only vs train-stop functionality, trackside installations, on-board installations, portable installations, characteristics/capacities/limitations of the wireless systems used, and identification and contact information of agencies that have tested and/or implemented them. FTA should use its existing authority, or seek the necessary authority, to require secondary protections on transit agencies.

Criteria/Methodology



Criteria used to evaluate this recommendation include the potential impact to safety, the potential impact to service, and the ability to further SMS.

The Federal Railroad Administration (FRA), the State of California, the American Public Transportation Association (APTA), and rail transit agencies (RTAs) have developed specific requirements, standards, programs, and procedures related to roadway worker protection (RWP). These various on-track safety programs are typically based on the strict adherence to various requirements, rules, standard operating procedures, and training. While these programs are an important element of RWP, these programs are human-factor dependent in that they depend on all roadway workers flawlessly implementing the rules, procedures, and requirements of these programs. Human error is a given, and when the requirements of an RTA's RWP program are not followed, roadway workers can be severely or fatally injured.

The State of California, through its Public Utilities Commission (CPUC), has implemented rules and regulations governing RWP provided by rail transit agencies and rail fixed guideway system through General Order No. 175-A adopted March 17, 2016 and April 12, 2016.[11] One element of this General Order requires that RTAs and Rail Fixed Guideway Systems must use early warning alarm technology in most situations. These early warning alarm technologies must be used as a secondary system *in addition* to the specific requirements outlined in General Order No. 175-A. This required secondary warning alarm gives an additional warning that a train is approaching the work zone, enhancing the level of safety. This system can reduce potential impacts to service by reducing and/or eliminating the potential for an accident occurring within the RTA right-of-way, thus reducing service stoppage while such an accident is addressed by responders and then investigated. Such early warning alarm systems would further SMS through the Safety Management Policy, Safety Risk Management, and Safety Promotion elements by making secondary alarm and/or warning systems part of an RTA's safety management policy, by including such technologies as part of the RTA's safety risk management of roadway workers, and using this technology in the RTA's promotion of safety to its workers throughout the agency.

Past NTSB safety recommendations are also included in the NTSB Special Investigation Report on Railroad and Rail Transit Roadway Worker Protection.[12] One such NTSB-issued recommendation from the WMATA Eisenhower Avenue Station accident which occurred November 30, 2006, is a finding to "Promptly implement appropriate technology that will automatically alert wayside workers of approaching trains and will automatically alert train operators when approaching areas with workers on or near the tracks"[13].
In addition to NTSB investigations, the TRB contracted TCRP Synthesis 95 – Practices for Wayside Rail Transit Worked Protection.[14] The TRB report outlined a number of technologies

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[11] General Order No. 175-A. Public Utilities Commission of the State of California. March 17, 2016, Decision 16-03-006, and April 12, 2016, Decision No. 16-04-014, Rulemaking 09-01-020. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M159/K905/159905345.pdf

[12] National Transportation Safety Board (2014). *Special Investigation Report on Railroad and Rail Transit Roadway Worker Protection.* Washington, D.C.: National Transportation Safety Board.

[13] NTSB 2009. RAB-08-02 - Railroad Accident Brief - Washington Metropolitan Area Transit Authority Metrorail System November 30, 2006, Recommendation R-08-04 (p. 9) Washington, D.C: National Transportation Safety Board

[14] National Academies of Sciences, Engineering, and Medicine (2012). TCRP Synthesis 95: *Practices for Wayside Rail Transit Worker Protection.* Washington, DC: The National Academies Press. https://doi.org'10.17226/14657.

that could be explored for use including rolling stock or high-rail-vehicle-mounted video cameras or sensors in the railroad industry, and other systems in the form of warning lights, audible devices, or portable trip or stop equipment to enhance the level of protection afforded to a work site. The report reviews what some different transit agencies throughout the USA and Canada are using.

Additionally, in general, any new safety technology should be carefully scrutinized for the potential for failure. Considerable research has been conducted regarding "automation bias," where individuals fail to utilize new safety technologies safely.[15] Considerable research cites a tendency to envision new technologies for "how they can work," to the neglect of "how they can fail." A strong safety culture has a strong focus on attending to, even "preoccupation" with, possible failure.[16] Human factors are generally and seriously neglected. Many such problems have been identified in accidents and research.[17]

Problems and errors include:

- *Errors of omission*, where operators become complacent, overly trusting the technology, failing to be vigilant, and failing to intervene when needed, [18] such as in the Uber self-driving car accident in Arizona where the driver wasn't paying attention; the system didn't recognize the pedestrian, and the car struck and killed her. [19] In an aviation example, an automated flight configuration warning system failed to alert a Delta crew that the airplane's flaps were not properly configured for takeoff. Apparently relying on the warning system, the crew did not manually verify the positions of the flaps, resulting in a crash shortly after takeoff.[20]
- *Errors of commission*, where the operator follows the directives or allows the automation to continue even though there's visual evidence indicating danger requiring operator intervention. For example, again in aviation, cases have been reported where

[15] For a recent summary of "automation bias," see Mosier, K. L., & Manzey, D. (2020). Humans and automated decision aids: A match made in heaven? In M. Mouloua & P. Hancock (Eds.), *Human performance in automated and autonomous systems: Current theory and methods* (pp. 19-41). Boca Raton, FL: CRC Press

[16] Weick, K., and Sutcliffe, K. (2015). Managing the unexpected: Sustained performance in a complex world. Hoboken, NJ: Wiley.

[17] For a discussion of this topic, plus additional references, see: *Before the Federal Railroad Administration of The United States Department of Transportation [Docket No. FRA-2018-0027] Request for Information: Automation in the Railroad Industry. Comments of the California Public Utilities Commission, May 31, 2018*.

[18] Mosier, K. & Skitka, L., (1996), "Human decision makers and automated decision aids: Made for each other?" in R. Parasuraman & M. Mouloua (Eds.) (1996), *Automation and Human Performance: Theory and Applications*. NJ: Erlbaum, pp. 201-220.

[19] NTSB (2019a). Collision Between Vehicle Controlled by Developmental Automated Driving System and Pedestrian. HAR-19-03. https://ntsb.gov/investigations/AccidentReports/Pages/HAR1903.aspx

[20] NTSB Report AAR-80-10, cited in Mosier & Skitka (1996), op.cit., and Billings, C. (1991). "Human-centered aircraft automation: A concept and guidelines." (Tech. Mem. No. 103885). Moffett Field, CA: NASA Ames Research Center.

crews erroneously relied on false alerts ("ghost" or "phantom" radar images,) rather than available disconfirming information, and committed risky incursions into conflicting airspace.[21]

- *Automation errors and design flaws,* including those which fail to account for human factors, have caused accidents, such as revealed in the Boeing 737 Max 8 tragedies and in auto-piloted automobile accidents. [22]
- *The need for more training* when automation takes over tasks, while somewhat counter-intuitive, is critical. Operators not only need to know how to operate the vehicle, but need to understand the technology, when to trust it, when to mistrust it, when to intervene, and how to intervene safely. [23]
- The conundrum where *the more reliable the technology, the more complacent an operator may be* and not intervene when needed; and the less reliable the technology, the more likely the operator will disengage it even when it can significantly assist with a critical task. [24]
- *Automation and technology may diminish operator skill development*, leaving operators unprepared to intervene when needed, especially in an emergency situation when responses need to have been firmly ingrained. [25]
- *Automation tends to leave the operator passive* and less aware of the real-time operational characteristics and context, and less prepared to intervene, with a difficult transition from a passive to an active control state. [26]
- *Employee and public acceptance is essential*. For example, in the 70's locomotive engineers occasionally used a "packing hook" (metal bar) to lock down the "deadman pedal," which is designed to engage the train's brakes when an engineer lifts his or her feet off of the pedal due to fatigue-induced sleepiness or other incapacitation.

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[21] Mosier & Skitka (1996). *op cit*.

[22] NTSB (2019a). Collision Between Vehicle Controlled by Developmental Automated Driving System and Pedestrian. HAR-19-03. https://ntsb.gov/investigations/AccidentReports/Pages/HAR1903.aspx

NTSB (2019b). Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance, ASR-19-01. https://www.ntsb.gov/investigations/AccidentReports/Reports/ASR1901.pdf

NTSB (2019c). Collision between a sport utility vehicle operating with partial driving automation and a crash attenuator. HAR-20-01. "The National Transportation Safety Board determines that the probable cause of the https://ntsb.gov/investigations/AccidentReports/Pages/HAR2001.aspx

NTSB (2020). Collision Between Car Operating with Partial Driving Automation and Truck-Tractor Semitrailer. HAB-20-01. https://ntsb.gov/investigations/AccidentReports/Pages/HAB2001.aspx

[23] Noy, I., Shinar, D., and Horrey, W. (2018). Automated driving: Safety blind spots. Safety Science, **102**, 68-78.

[24] *Ibid*.

[25] *Ibid*.

[26] *Ibid.*

- *Root-cause analysis must be performed* to avoid blaming employees for not handling the situation. A previous TRACS report, presented “The Arrow,” which is a graphic representing different levels of responsibility for causation or preventing an accident. At the “arrow’s sharp end” is the employee most proximal to the event, who appears in the position to be able to prevent the occurrence. But responsibility for prevention runs up the “arrow” to supervisors, managers, trainers, policies such as rest opportunities, to regulators, legislators, and finally the public. Developing details of the Boeing 737 Max 8 tragedies are partly being attributed to very high levels in the organization where competition with Airbus prompted a rush to deliver, and possible lax regulatory oversight. [27]
- *RTAs’ experiences must be considered, including any desire to replace a human-provided protection with a technology*, thus without the redundancy that technology should provide. For example, agencies may wish to replace flaggers with early-warning technology too generally and when the technology hasn’t been sufficiently tested in all possible contexts.
- *Technology has enhanced ability to produce data, but how is it then used?* The human is still in the loop, and failure may just shift to a different and less stimulating task. For example, the FRA is examining autonomous track inspection technology, which will provide considerable data. [28] Being vigilant while sifting through a lot of data may be considerably more difficult than being vigilant while attending to real-world infrastructure where all sensory input is real, not virtual or condensed into reams of numbers.
- And finally, *technology must be evaluated in a socio-technical context, including security*.[29] For example, real-time worker-presence detection coupled with PTC technology to stop trains in time to avoid roadway worker strikes may not work well for rail transit vehicles, since workers can occupy into the track space at the last minute, long after any train has the needed stopping distance, such as when a worker may want to quickly grab something out of the trackway. Security of operations may also render PTC vulnerable to malicious behaviors. Pranksters or worse may learn how to set off a train-stopping detection and cause havoc to service[30] and create complacency (“crying

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[27] https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/

[28] https://railroads.dot.gov/elibrary/autonomous-track-geometry-measurement-technology-design-development-and-testing

[29] For a more comprehensive discussion of safety technology and socio-technical systems, see Carayon, P., Hancock, P., Leveson, N.G., Noy, Y.I., Sznelwar, L., van Hootegem, G. (2015). Advancing a sociotechnical systems approach to workplace safety – developing the conceptual framework. *Ergonomics: Special Issue on Sociotechnical Systems and Safety*, **58**, 548–564.

[30] This issue was raised in public comments during TRACS July 22, 2020, virtual meeting.

wolf") in the long term. Socio-technical interactions may exist in the implementation and use of RWP early warning systems and must be anticipated and evaluated.

Key Takeaways

Takeaways

- RWP safety technologies have already been required by California.
- RWP safety technologies have the potential to provide positive impacts to safety and service.
- RWP safety technologies have the ability to further SMS.

This recommendation addresses each of these three key takeaways. First, the State of California, which has the greatest number of RTAs overseen by a State Safety Oversight Agency (SSOA), has already mandated the use of early warning alarm technology. This gives credence to this recommendation for the FTA to require the use of secondary warning systems at all RTAs in the nation. Five different vendors provided information through presentations to the TRACS Committee about the products they have available to implement to provide a secondary level of RWP protections.[31] While most of these vendors have commercially available systems, they note that there is a long-standing industry barrier to enter and a reluctance to adopt these new technologies in these mostly older systems. Some commented that when they can know there is a market for a product, then they can confidently invest in development. One vendor noted that what prompted development for them, and as well for others, was a state regulation requiring secondary warning systems.

Second, as has been shown, RWP safety technologies have the potential to provide positive impacts to both safety and service. Requiring the use of secondary warning systems will increase safety to roadway workers and the traveling public, and will have a positive impact on service as fewer accidents involving roadway workers will equate to a decrease in delays in rail transit service. Finally, secondary warning systems would further SMS through a number of the SMS elements. Requiring the use of secondary warning systems would further SMS at RTAs as secondary warning systems will support Safety Management Policy, secondary warning systems will be directly involved in an RTA's Safety Risk Management process, and this additional warning system can be used as part of the Safety Promotion element at RTAs showing management's commitment and care of their employees' safety.

Information Gaps

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[31] The presentations may be found at the following link: https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-programs/safety/147776/tracs-technology-presentation-february-2020.pdf

- Information on the number of agencies that have implemented RWP safety technologies to address NTSB findings and FTA's Safety Advisory 14-1: Right of Way Worker Protection.
- What the various SSOAs are doing with respect to RWP.
- A relevant working definition of redundant protection.

This recommendation discusses each of these information gaps. By requiring secondary warning systems to be installed at all RTAs, the recommendations focusing on this issue in NTSB findings and FTA's Safety Advisory 14-1 will be addressed. This recommendation would answer the question of what various SSOAs are doing with respect to RWP in that all RTAs would be required to have secondary systems. Systems installed can be tracked to see what each RTA has installed, which would answer the SSOA question. Finally, secondary warning system requirements would provide an initial example definition of redundant protection. Redundancy not only means there is a fallback protection if the primary protection fails, but that it is independent from the primary protection such that primary failure cannot cause failure in the secondary, redundant systems. For example, if a primary and secondary system were both electrically powered, and used the same power source, then power failure would cancel both systems; those two systems must have separate power sources, including separate backup power. The RWP secondary warning systems would provide that second level of safety protection by making it redundant to an RTA's primary protection of roadway workers, and by not being subject to the same failure event.

Additional Justification

The NTSB has made numerous findings regarding the need for additional protections for roadway workers and has made numerous subsequent recommendations to the FTA, to transit agencies, and to other related agencies.[32] While many of these recommendations address standard operating procedures and comprehensive job briefings, the committee reviewed reports that show that secondary RWP systems should be used. The State of California, the SSOA with the greatest number of RTAs, believes this is an important enough issue that it has required RTAs early warning alarm technologies in its General Order 175-A.[33] The NTSB recommended use of redundant safety systems, and the Transportation Research Board has issued a report, *TCRP Synthesis 95*, outlining transit RWP practices.[34] Also helpful will be the

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[32] National Transportation Safety Board 2014. *op cit*..

[33] General Order No. 175-A. Public Utilities Commission of the State of California. *op cit*.

[34] National Academies of Sciences, Engineering, and Medicine (2012). *op cit*.

final FTA report prepared by the Center for Urban Transportation Research at the University of South Florida, currently available as an interim report.[35]

Conclusion

This recommendation should be implemented by FTA because it will provide redundant safety protection to all roadway workers and will address FTA's Safety Advisory 14-1: Right-of-Way Worker Protection[36] and numerous findings from NTSB regarding the deaths of roadway workers at numerous RTA properties (see list of properties and fatalities listed in FTA Safety Advisory 14-1).

Reference Sources and Additional Recommended Reading

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[35] US Department of Transportation, Federal Transit Administration (2016). *2016 Safety Research Demonstration (SRD) Independent Evaluation: Interim Report*. Washington, D.C.: Federal Transit Administration. https://www.transit.dot.gov/sites/fta.dot.gov/files/2020-05/FTA-Research-Report-No.-0166.pdf

[36] Federal Transit Administration. (2013). *Safety Advisory 14-1: Right-of-Way Worker Protection*. *op cit*.

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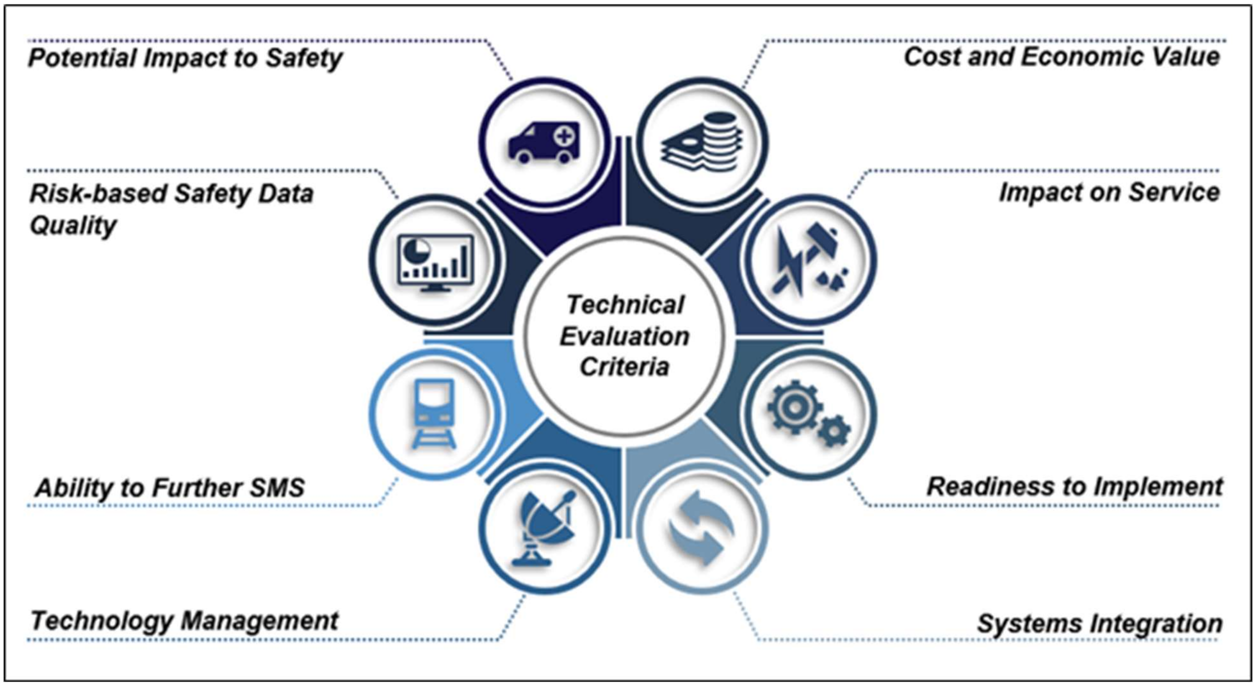
RWP Recommendation #2 – Funding for New Research and Implementation of New Systems and Technology

Recommendation

The Committee recommends that FTA provide funding for research and implementation of existing and new systems and technology. FTA should provide grants for 1) research and testing of new RWP safety technology, including secondary protection systems, and 2) to assist transit agencies with the financial burden of implementing such systems.

Criteria/Methodology



Criteria used to evaluate this recommendation include the potential impact to safety, cost/economic considerations, the potential impact to service, readiness, the ability to further SMS, risk-based safety data quality, systems integration, and technology management.
Some vendors discussed data collection and reporting abilities of their systems. Such systems could be used to provide data for risk-based safety data analysis, but it is difficult to anticipate the quality of this data from the presentations. Some vendors provided information that their systems have been deployed at some rail transit agencies (RTA), which indicates that some of these systems are ready to implement and have been able to integrate into the RTA systems on which they are being used. Some vendors noted the time and cost it takes to implement these systems, and that weather can have some impact on these systems. Some systems are

currently in development and not ready for deployment. FTA contractors provided an interim report regarding safety research demonstration projects looking at some of these systems.[37]

From the vendor presentations,[38] it is clear that the proposed systems have a potential positive impact to safety and revenue service in that the secondary warning system can help in alerting roadway workers who may not be paying attention to lookouts for approaching trains because they are concentrating on the work task at hand. These workers who are not paying attention as is typically required by standard operating procedures are at greater risk for an accident resulting in an injury or fatality. The secondary warning system will assist by giving a second level of warning, which will enhance the safety of the worksite. Service schedules can operate with fewer disruptions with any decrease in accidents in the right-of-way. Fewer accidents would prevent service stoppages as emergency responders and investigators perform their duties. Systems that include positive train control access by the employee-in-charge (EIC) not only will provide more confidence in safety, but may facilitate minimizing service disruptions. Also, from the vendor presentations, these secondary systems will further RTAs' SMS through all four elements, including Safety Management Policy, Safety Risk Management, Safety Assurance, and Safety Promotion. Use of secondary systems is included in the RTA's safety management policy because it shows roadway workers the commitment by the agency to provide a safe work environment. RTAs can use secondary RWP warning systems as a safety measure to provide a second level of risk management in addition to the RTA's standard operating procedures for RWP workers. The data that potentially may be obtained from these secondary warning systems may provide additional data and input into the RTA's safety assurance process to evaluate trends and issues that may be occurring with RWP workers. The data and analyses can lead back to additional safety risk management efforts in how secondary systems can be used to reduce and/or eliminate RWP accidents, thus improving safety. Finally, secondary warning systems can be used as a safety promotion to show all related employees the necessary vigilance and diligence in their rail-related functions and how use of such equipment will promote the safety of roadway workers as they are out on RTA alignments.

In addition to the vendor presentations, TCRP Synthesis 95 – Practices for Wayside Rail Transit Worker Protection,[39] outlined a number of technologies that could be explored for use including rolling stock or high-rail-vehicle-mounted video cameras or sensors in the railroad industry, and other systems in the form of warning lights, audible devices, or portable trip or

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[37] US Department of Transportation, Federal Transit Administration (2016). *op cit.*

[38] February 25, 2020, vendor presentations, including Bombardier TrackSafe, Emtrac ITS Connected City, Metrom Rail Aura Train Control System & Integrated Worker Protection Function, Miller Ingenuity ZoneGuard, Protran Technology Safety Solutions RWP Systems, and Trapeze Group Roadway Worker Protection System. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-programs/safety/147776/tracs-technology-presentation-february-2020.pdf

[39] National Academies of Sciences, Engineering, and Medicine (2012). *op cit*.

stop equipment to enhance the level of protection afforded to a work site. The report reviews what some different transit agencies throughout the USA and Canada are using.

The committee reviewed an additional article about some technologies being explored to improve safety of railyard workers to increase overall situational awareness.[40] Technologies studied in this paper include vision-based systems, software-defined RADAR, and wearable systems used as personal health monitors and alerting systems. These systems were also considered when used in combination with each other to provide reliable observations under a wide range of weather conditions. Field tests were performed at a Union Pacific Railroad yard, and the results showed great potential. The data showed that train tracking is possible. The committee prepared and presented several papers during this study, and believes there is great potential in this technology. However, time and resources did not permit further research into these technologies.

As was stated by some of the early warning technology vendors, cost and economic considerations are something to be considered when implementing these systems. These systems can have significant costs, including equipment purchase, installation, configuration, testing, implementation, maintenance, and management. This process may take a substantial amount of time. Some transit agencies expressed concerns about such new and novel technology being ready and being integrated into their existing systems. There is an important caveat to vendor involvement: Committee members noted the concerns of development efforts without promise of a sale at the end, especially considering budgetary issues transit agencies currently face. A couple vendors expressed concern about investing in development without a known market.

Key Takeaways

Takeaways

- RWP safety technologies can be purchased and installed from a number of vendors.
- RTAs may believe that the RWP safety technologies are too new, or have not been rigorously researched and confirmed to be compatible with their system.
- The implementation of these systems involves substantial capital investment and requires significant time.

Five vendors presented RWP safety technologies that can be purchased and installed, either now or in the near future: Protran, Metrom Rail's *Aura* system, Miller Ingenuity's *ZoneGuard*,

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[40] *Ibid*.

EmTrac, and Bombardier's *TrackSafe*.[41] However there seems to be hesitation by RTAs to purchase these technologies given how new they are, and the lack of rigorous research and testing to confirm that these systems are safe and compatible with the different RTA systems. Additionally, RTAs are burdened with multiple decision points of how to spend budgets: Should they purchase a RWP system? Or should they use this funding to go toward their state-of-good-repair condition to resolve any transit asset management plan backlog that they must assess and address in a four-year plan?

This recommendation discusses each of these three key takeaways. TRACS recommends that funding be provided for research on existing and new systems and technology and recommends that funding be provided for implementation of existing and new systems and technology. Funding for research and implementation would enable additional research and testing for existing and new RWP technologies. This could help RTAs understand how they can incorporate or adapt existing and new RWP safety technology systems into their rail systems, including how they can cover the capital costs of purchasing and installing such systems.

Information Gaps

- Lack of any significant research rigorously testing the validity of existing technologies.
- Lack of research examining the applicability of technologies that are in use on railroads for use on rail fixed guideway systems.
- Lack of information regarding on-going maintenance costs once an RWP system has been installed.
- Lack of information on testing, implementation, and cost of other types of RWP systems dealing with natural hazards, falls, bucket lifts, or other types of accidents as outlined by the NTSB Special Investigation Report on Railroad and Rail Transit Roadway Worker Protection. An overall lack of quantitative evidence presents a sizable information gap for this issue.

This recommendation addresses each of these information gaps. The committee recommends:

- That funding be provided for the rigorous testing of the validity of existing technologies.
- That funding be provided for research to determine if parallel technologies being used on railroads are compatible, or with some changes, can be adopted for use by rail fixed guideway systems.
- That funding be provided for testing and implementation of other types of technology solutions to address roadway worker accidents involving natural hazards, falls, bucket

[41] The presentations may be found at the following link: .https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-programs/safety/147776/tracs-technology-presentation-february-2020.pdf

lifts, and other types of accidents as outlined by the NTSB in their Special Investigation Report.[42]

- That funding be provided for on-going maintenance costs of RWP systems once they have been installed, as well as for the research to identify what is necessary for on-going maintenance of these systems.

Additional Justification

The NTSB has made numerous findings and recommendations regarding the need for additional protections for roadway workers to the FTA, to transit agencies, and to other related agencies.[43] While many of these have involved recommendations for standard operating procedures and comprehensive job briefings, TRACS reviewed reports that show secondary RWP systems could prevent incidents. The State of California decided that this is an important enough issue, that in its General Order 175-A,[44] it required that early warning alarm technologies be used by RTAs.

Conclusion

FTA should implement this recommendation because it addresses FTA's Safety Advisory 14-1: Right-of-Way Worker Protection[45] and findings from the NTSB regarding the deaths of roadway workers on numerous RTA properties (see the properties and fatalities listed in FTA Safety Advisory 14-1).

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[42] National Transportation Safety Board 2014. Special Investigation Report on Railroad and Rail Transit Roadway Worker Protection. Washington, D.C.: National Transportation Safety Board.

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[44] General Order No. 175-A. Public Utilities Commission of the State of California. *op cit*.

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RWP Recommendation #3 – Minimum RWP Safety Requirements as the Basis for Secondary Warning Systems

Recommendation

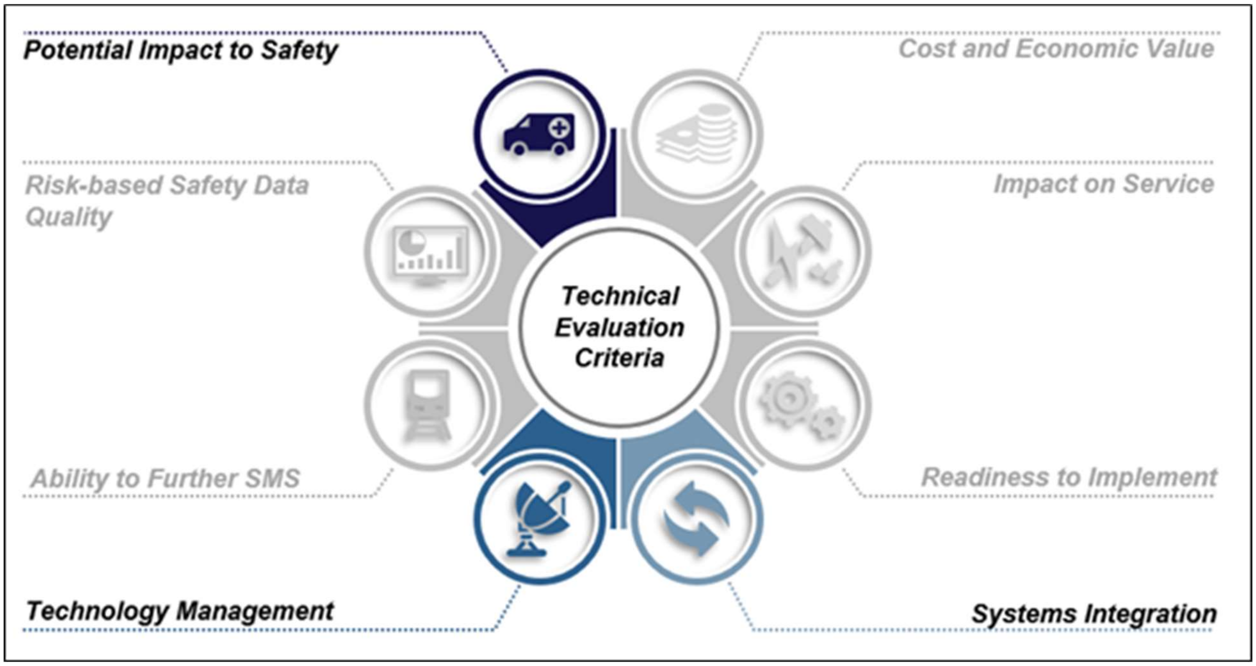
The Committee recommends that FTA 1) develop minimum safety RWP rules/requirements, and safety performance standards as primary protections and 2) assist with implementation of any secondary RWP safety systems.

FTA should create a “use-case” list and develop minimum primary protection requirements including rules, procedures, equipment, safety briefings, provisions for good-faith challenges and non-punitive safety reporting, which will serve as the base upon which a secondary warning/protection system is layered as a redundant protection. The primary protections should include options that cover appropriate application to all use-cases. While no technology is 100% reliable, multiple systems in duplication are critically important in case one system fails. This TRACS report directs the reader to forthcoming information regarding different use-cases and possible options for the primary protections that will be the essential basis for adding secondary protections[46]—especially any RWP safety technologies such as early warning systems.

The Committee recommends that the non-punitive safety reporting task be integrated into the recommendations provided by the Employee Safety Reporting subcommittee. Notably, this RWP safety technology recommendation should incorporate concerns about the use of technology to provide both primary and secondary safety systems, such as reliability, problems with use, and human error with usage – especially as these existing and new technologies become adapted and implemented on the nation’s rail transit agencies (RTAs). Careful consideration must be given to how reporting systems and good faith challenges can cover all the possible safety issues with such technologies.

[46] See TTCI’s preliminary executive summary in this recommendation below.

Criteria/Methodology



The protections should be evaluated on their susceptibility to failure, and how they can provide truly independent layers of protection for each use-case. The related concepts of independent redundancy and single-point failure must be addressed. NTSB recommendations should be addressed in relation to implementation. Taken together, the protections used must cover all variations of rail transit systems, especially describing all use-cases and how they provide positive primary protections for each case, and how they create the underlying basis for secondary protection systems as additional safety redundancy. FTA Safety Advisory 14-1, APTA Roadway Worker Protection Standards, California Public Utilities Commission (CPUC) General Order 175-A, and the Transportation Technology Center, Inc.'s (TTCI) survey and compilation of use-cases are important resources.[47]

Key Takeaways

- RWP safety technologies are available to augment primary protections.
- Independent redundancies must be based on the primary protections, and adapted to each use-case, avoiding potential for single-point failures.
- RWP safety technologies are being used and TRACS would benefit from finding out RTA experience with them in relation to the primary protections and how they are applied in different use-cases.

[47] As stated earlier in this TRACS report, TRACS has been informed that TTCI's report should be available in 2021.

- TRACS would benefit from working with any existing FTA RWP safety technology work, including those which followed from Safety Advisory 14-1, and how they inform the above points.
- Having reviewed a number of accident investigation reports, Committee members note that secondary warning systems would have been beneficial in each instance.

Information Gaps

- Comprehensive accounting of what RTAs are using, if any, for secondary warning systems.
- Information regarding the experience with the new technologies available in the transit industry for RWP.
- Information regarding the evolution of technologies evolving with testing and experience on RTAs.
- Information regarding newer RWP safety technologies are being planned.
- Information from RWP fatality investigations from 2008 through 2020.
- No assigned papers addressed any rules, procedures, equipment, safety briefings, allowance for good faith challenges, or non-punitive safety reporting that would comprise the primary protections for RWP; papers added by the subcommittee, FTA (Safety Advisory 14-1) and CPUC General Order 175-A, either directly or indirectly describe these aspects of RWP as applied to use-cases, but more comprehensive and up-to-date research is needed.
- Information regarding the following, by use-case:
    - Effectiveness and operational ease of use.
    - Feasibility and practicality of the emerging technology and existing technology.
    - Cost.
    - Upkeep/maintenance perspective.
    - Discussed contacting transit agencies that have implemented electronic warning/control systems, such as Protran, Metrom, ZoneGuard, TrackSafe, and EmTrac to obtain information on effectiveness, feasibility, and practicality for transit system applications.
    - RWP and implementation of RWP technologies under SMS.
    - Determine how protections and standards can be integrated into the SMS framework and what changes may be necessary to bridge any gaps between SMS and standards.
    - FTA work following the NTSB's RWP recommendations and FTA's Safety Advisory 14-1, and how the FTA might assist with new technology rollout.

- What might be impeding the comprehensive utilization on all relevant RTAs, e.g., lack of funding, lack of statutory and/or regulatory authority and requirements, evidence of effectiveness, knowledge of how to integrate with current protections.

Future gaps include the potential usefulness of safety information that would otherwise be lost if safety reports and complaints, and good-faith challenges to safety briefings, were met with punitive responses. Protections would assist in motivating employees to report safety issues, close calls, inadvertent non-compliance, and concerns about the safety being provided as presented in safety meetings. Such reports are critical leading indicators, and are often the best source of information needed in any Safety Management System.

Additional Justification

The NTSB has recommended additional protections for RWP rail roadside workers since at least 2008.[48] Since and including that time, the NTSB has issued at least 13 different recommendations to the industry and FTA.[49] These recommendations are paralleled by recommendations to the railroad industry. Together, the accidents experienced by rail transit and railroad workers provide evidence of the need for better protections. Notably for this recommendation, each accident investigated provides not just evidence for the need, but how the existing rules, practices, and procedures failed – within a particular use-case.

Appendix A-4 provides short descriptions of fourteen RWP failures that ended in fatalities, in the years 2000 through 2008, which were subsequently investigated by the NTSB and/or the CPUC.[50] The FTA noted twenty-eight fatalities occurred on RTA properties from 2002 through 2013. This report should be augmented by finishing a number of tasks that would provide further justification, including completing this appendix for the years 2008 through 2020. Short descriptions of each rail transit and railroad RWP fatality investigated by the NTSB and or SSOAs during this time should be added to better inform the reader of the real-world experience that justifies further action.

TTCI's forthcoming report will include a survey of use-case applications as well as additional research. TRACS received the following preliminary Executive Summary from TTCI for inclusion in this TRACS report:

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48 This recommendation letter, dated January 30, 2008, is available on the NTSB website at http://www.ntsb.gov/.

49 See National Transportation Safety Board (2013). Letter to the Honorable Peter M. Rogoff, Administrator, Federal Transit Administration, December 19, 2013, recommendations R-13-39 and R-13-40. Washington, DC.

50 These fatality descriptions were taken from the CPUC staff's report created at the beginning of its RWP rulemaking in 2009: California Public Utilities Commission, Consumer Protection and Safety Division (2009). *Personal Electronic Device Use on Rail Transit Systems: Report For R.08-10-007*. December 24, 2009. https://docs.cpuc.ca.gov/PublishedDocs/EFILE/RULINGS/113001.PDF

Executive Summary

Transportation Technology Center, Inc. (TTCI), in support of the Center for Urban Transportation Research (CUTR), was tasked by the Federal Transit Administration (FTA) to research and develop findings to improve the safety of transit rail roadway workers.

The project objectives include the following:

1. *Conduct a literature review to evaluate current industry practices and technologies in use for roadway worker protection.*
2. *Conduct a risk/hazard analysis of current practices including an analysis of available incident reports, an industry-wide survey and incident data from the National Transit Database (NTD).*
3. *Development of high-level concepts of operations (CONOPS) for roadway worker alerting/protection that can be used to reduce identified risks associated with the work performed by roadway workers.*
4. *Conduct a GAP analysis between current available technologies and operational methods, and emerging technologies that can improve roadway worker safety.*
5. *Summarize the findings in a final report.*

The literature review included reviewing available literature on incident reporting and safety practices in North America as well as international transit agencies. An industry survey was sent out, with help from the American Public Transportation Association (APTA), to provide insights into procedural and operational differences among individual transit agencies, but responses indicated that the majority of agencies are using a modified version of the Federal Railroad Administration's regulations (part 214) to address their roadway worker protection practices. Incident reporting revealed there are several potential hazards that need to be addressed, including 1) miscommunication 2) inattention 3) improper protection 4) incapacitation.

Review of available emerging technologies determined that most are only able to provide a secondary level of protection for roadway workers at this time. However, by overlaying these onto existing policies and procedures, relative risk to roadway workers can be reduced. Safety concepts such as these provide an opportunity for enhanced roadway worker safety in almost any application.

TTCI has developed a comprehensive document describing all possible use cases that involve transit rail roadway worker protection. These use cases were used as the basis for the risk and hazard analysis as well as the development of the high-level CONOPS for a system that will enhance RWP. These use cases will be useful for transit agencies to use as a benchmark and identify most significant hazards encountered by roadway workers and improve their RWP policies and procedures.

As part of this research, TTCI has developed a hazard assessment matrix program designed to assist in determining the relative risk posed by any task to be performed by a roadway worker. The development of this program was based on the data available and has incorporated research in the field of human factors.

TTCI has also developed a high level CONOPS that is intended to reduce the risk of transit rail roadway workers while engaged in activities within the roadway. This CONOPS can be utilized in conjunction with current practices to improve overall safety for roadway workers. It essentially includes a suite of risk reducing system concepts, which, when used together or individually, will improve worker safety by reducing specific risks by enhancing situational awareness of roadway workers. The user platform for the risk reduction CONOPS would be a small portable device that will be able to be worn by roadway workers, watchman, and/or employee-in-charge.

A GAP analysis on the safety concepts was conducted and revealed some potential shortfalls. The biggest one is that secondary protection device warnings cannot replace proper adherence to safety rules, and that even those type of devices can be ignored by workers in the field, thus negating any potential positive safety benefits.
The final report will include research details and findings and will be published by the Federal Transit Administration on https://www.transit.dot.gov/research-innovation/fta-reports-and-publications.

TRACS has been informed that TTCI's report should be available in 2021.

Conclusion

There is sufficient evidence that additional roadway worker protections are needed. The basis for implementing new secondary protections must be the existing protections that provide primary protection for roadway workers. Primary protection should include rules, procedures, equipment, safety briefings, allowance for good faith challenges, and non-punitive safety reporting. To create robust primary protections, a comprehensive inventory of use-cases should be established, at least those applicable at an RTA, but also ideally by the FTA comprehensively for all use cases in the industry. Especially given the newness of the RWP safety technologies, it must be clear that these technologies are being added as independent redundancies to a robust set of primary protections based on all possible use-cases.

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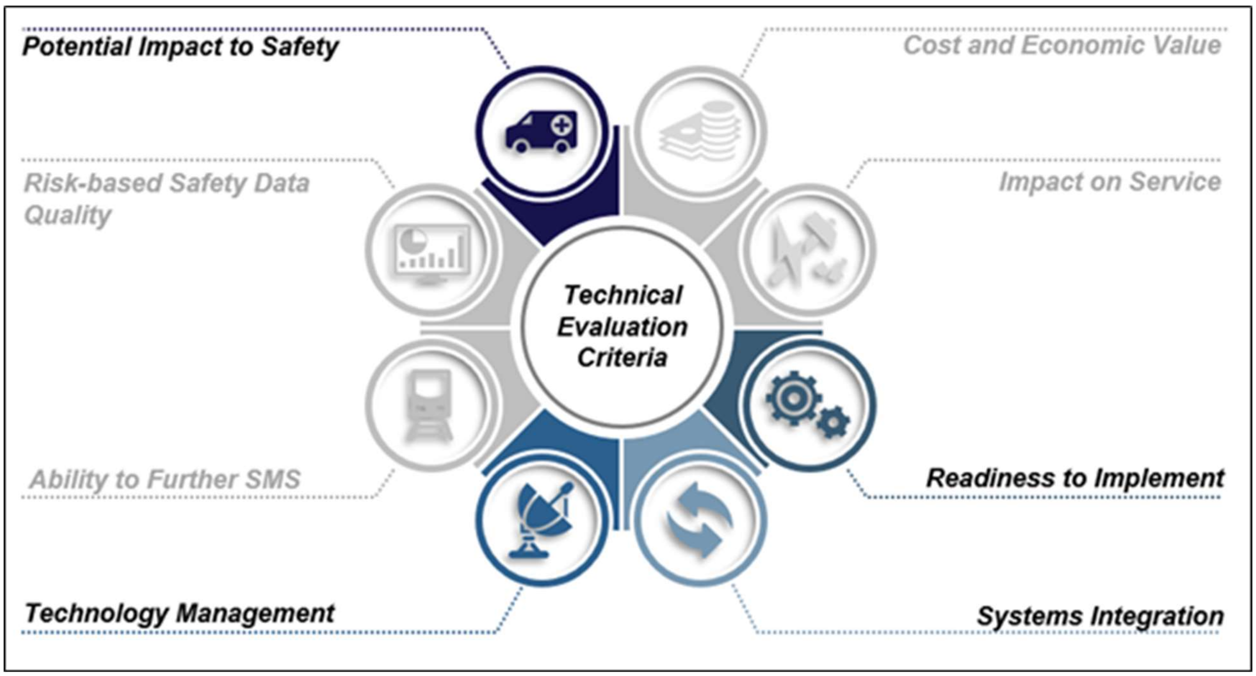
RWP Recommendation #4 – Develop RWP Safety Technology Reliability Criteria

Recommendation

The Committee recommends that FTA develop criteria to determine the reliability of RWP safety technology, utilize those criteria to ascertain the reliability of the different technologies, and provide the information to RTAs and SSOAs.

FTA should create guidance on the ability of available RWP safety technologies to function error-free, by identifying the characteristics of each different technology, such as wireless frequency and technology used, and identifying those circumstances where failures might occur, such as in tunnels, on curves, in dense urban areas with frequency interference, and identify and provide the means to evaluate, and provide evaluations of, these technologies' security protections.

Criteria/Methodology



The protections should be evaluated on their susceptibility to failure, either through technological failure and/or environmental conditions. RTA testing and implementation experience, plus engineering expertise should be utilized to evaluate each technology, not only in design and the known characteristics of each technology, but in the field experience to-date. FTA should continue to fund field testing and make available all testing results to the RTAs and SSOAs. FTA should investigate all transit agencies that have implemented electronic warning/control systems, such as Protran, Metrom, ZoneGuard, TrackSafe, and EmTrac to obtain information on reliability in transit system applications.

Reliability issues and experiences should be reported immediately to an FTA database. Such reporting should be included in any employee reporting system to optimize employee motivation to report. Reports should be encouraged through use of non-punitive confidential reporting systems.

Key Takeaways

- RWP safety technologies are available, but differ in the types of technology used, and in their ability to function error-free in different applications and environments.
- RWP safety technologies are being used and FTA, RTAs, and TRACS would benefit from finding out RTA experience with them.
- TRACS would benefit from working with any existing FTA RWP work, including those which followed from Safety Advisory 14-1, in order to complete a comprehensive report on RWP safety technologies.

Information Gaps

- Information about the reliability of the newer technologies available in the transit industry for RWP.
- Information about upkeep and maintenance issues and how they might affect reliability.
- A structure for reporting any technological failures, no matter how small or seemingly inconsequential.
- TRACS had no access to any papers describing the limitations of any of the technologies and their potential for failure.
- TRACS has neither a comprehensive compilation of secondary warning systems in use or in testing on the nation's RTAs, nor any compilation of the experience or lessons learned through such testing, development, adaptation, and use.

Additional Justification

Reliability is an essential part of any safety intervention. Any technological failure would render the protection useless and potentially endanger roadway workers.

Conclusion

FTA should determine the reliability of any RWP safety technology system, and ensure that the information gathered is readily available to RTAs and SSOAs.

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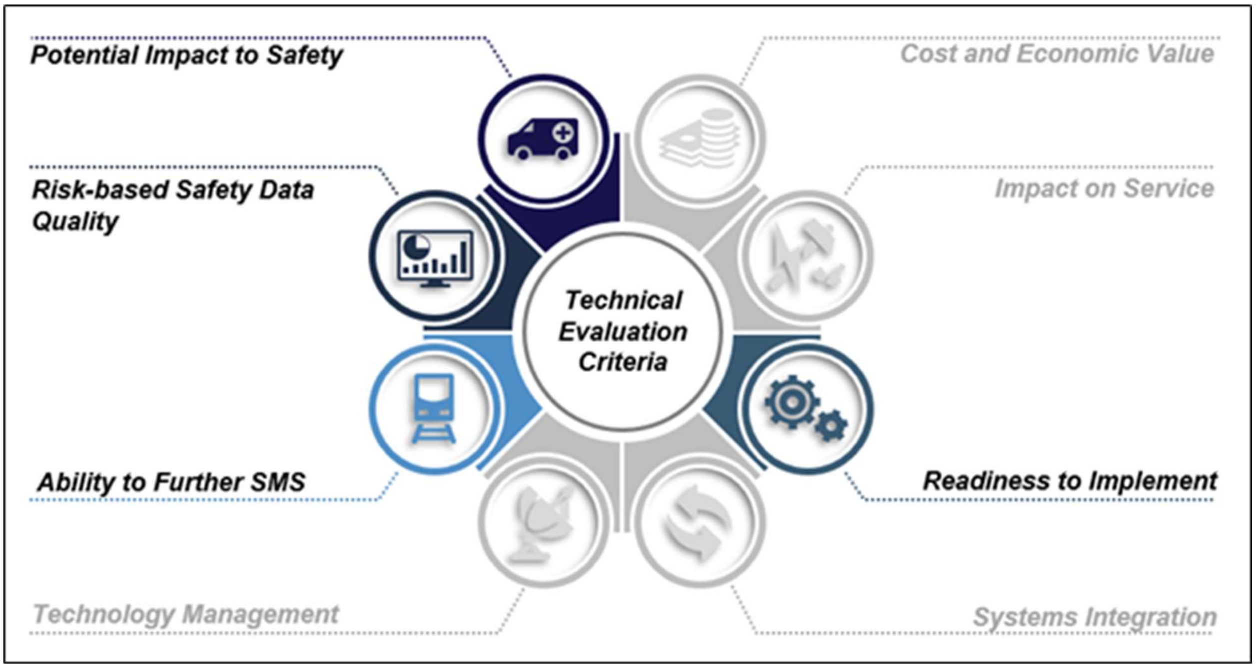
RWP Recommendation #5 – Development of Risk-Based Safety Metrics including Leading Indicators

Recommendation

The Committee recommends that FTA develop risk-based safety metrics including leading indicators.

Criteria/Methodology



Criteria used to evaluate this recommendation include the potential impact to safety, implementation readiness, the ability to further SMS, and risk-based safety data quality. The term metrics is sometimes mentioned, but not necessarily defined. Of the literature reviewed for this topic, only TCRP Synthesis 95 – Practices for Wayside Rail Transit Worked Protection[51] mentions tracking and analyzing data on incidents, near misses, and other metrics.

The industry seems to focus on lagging indicators, analyzing data after the fact, which does not provide proactive information on the potential impact to safety, but rather analyzing safety issues after they have occurred and using that data to try to mitigate repeats of such hazardous situations in the future. Risk-based safety metrics, which include leading indicators, would go a long way towards determining what may have a potential impact to safety before events happen. Furthermore, technological advancements are increasingly being assessed more with leading indicators, relative to lagging indicators.

[51] National Academies of Sciences, Engineering, and Medicine (2012). *op cit.*

Looking at the readiness criteria, transit agencies should be ready to collect the data needed to analyze the appropriate safety metrics. This data collection should include any leading indicators. If given a greater range and type of metrics, transit agencies should be able to produce the data for these metrics.

Development of risk-based safety metrics including leading indicators will further SMS for RTAs in the areas of Safety Risk Management and Safety Assurance, and perhaps in Safety Management Policy. Risk-based metrics including leading indicators are essential as part of the RTA's safety risk management process by providing the feedback necessary to understand the effectiveness of its risk management processes, as well as indicate where improvements might be needed.

Once an RTA has the metric data that has been collected in the safety risk management process, it will be able to use its safety assurance process to determine how best to mitigate issues discovered. Knowing the risk-based safety metrics, including leading indicators, can assist the transit agency as it implements or enhances its safety management policy. The developed metrics could be used to continuously improve the safety management policy by creating mitigations for issues that have been identified.

Through the development of risk-based safety metrics including leading indicators, these metrics can be developed to ensure that quality risk-based safety data is being collected by RTAs not only for use in the agencies' own data analyses, but also allowing for larger, nationwide analysis since the data should be comparable from agency to agency. This type of analysis would allow for a better understanding of rail transit agencies as a whole, which could lead to future development of various protection measures for roadway workers.

The Committee recommends that FTA create a list of evaluation criteria, indicators, and metrics (CIM) adapted to the use intended for those metrics in evaluating RWP safety technology. Three categories of use should be used:

1) *For evaluation of available RWP safety technologies to assist in procurement decisions*. Such CIM would include any available leading indicators, such as any history of false positives, false negatives, potential for overdependence/complacency, and any other human factors concerns, such as were discussed earlier in Recommendation #2.

2) *For basing the leading indicators in the possible impacts of successes and failures of future implementation*, the potential for each implementation to reduce or eliminate the potential for fatalities, injuries, near-misses. Posed as a question: How and what does this leading indicator tell us about the potential to improve safety, including:[52]

[52] February 25, 202 FTA PowerPoint presentation by Kara Waldrup, p. 7.

- Potential to significantly reduce fatalities.
- Potential to significantly reduce injuries.
- Potential to reduce safety events.
- Potential to improve system reliability.

3) *For post-implementation evaluation and continuous improvement*, both leading and lagging indicators should be used, including those gleaned from non-punitive reporting systems.

Where respectively appropriate, actual and normalized CIM should be established. Normalizing data sources should be identified and established that appropriately communicate the risk represented by the data.

Key Takeaways

- Development of risk-based safety metrics - including leading indicators - would be beneficial for all rail transit agencies.
- Such risk-based safety metrics, if nationally consistent, would enable a larger scale analysis of RTA operations throughout the nation.
- The development of risk-based safety metrics would further the collection of quality data and data that can be used in an RTA's SMS development and implementation.
- A prior TRACS report provides an in-depth discussion of research and theory on this topic.[53]

This recommendation addresses each of these three key takeaways by recommending that risk-based safety metrics - including leading indicators - be developed. The FTA development of such risk-based safety metrics would ensure that the metrics would be common throughout the nation and would give FTA an opportunity of performing an industry-based risk analysis. Finally, with FTA developing such risk-based safety metrics, FTA could ensure that data collected for the metrics would be quality data that could be included in an RTA's SMS development and implementation.

Information Gaps

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[53] USDOT, Federal Transit Administration (2017). Transit Advisory Committee for Safety (TRACS) 16-02 Final Report, *Safety Data and Performance Measures in Transit*. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-guidance/safety/64016/safety-data-and-performance-measures-transit-tracs-16-02-final-report.pdf

- Lack of a review of any updates of progress in implementing the recommendations from the TRACS Report 16-02, *Safety Data and Performance Measures in Transit*.[54]
- Any information on applications of TRACS Report 16-02.

The committee recommends that a review of subsequent research be completed to develop the risk-based safety metrics including leading indicators, and investigation into any applications or current work to implement the recommendations from the previous TRACS report. Such research will be necessary to advance this issue, and should include analyzing the quality of the data being collected for each current metric and for any new developed metrics.

Additional Justification

As part of the Moving Ahead for Progress in the 21st Century Act (MAP-21), FTA implemented rules that require review and analysis of data as part of the 49 CFR Part 673 - Public Transportation Agency Safety Plan and 49 CFR Part 674 – State Safety Oversight. Having consistent metrics throughout the RTA industry would greatly help RTAs and SSOAs in their data review and analysis charges. These metrics would also allow consistent analysis or risks throughout the RTAs and SSOAs.

Conclusion

This recommendation should be implemented by FTA because it will provide consistency in metrics and gathering quality data to analyze these risk-based metrics, including leading indicators. This data will also be important to RTAs and SSOAs in implementing the requirements of 49 CFR Parts 673 and 674, and will allow for an improved implementation of SMS throughout the industry. It will also be important to continue the progress made in the previous TRACS report, *Safety Data and Performance Measures in Transit*.[55]

Reference Sources

National Academies of Sciences, Engineering, and Medicine 2012. *TCRP Synthesis 95: Practices for Wayside Rail Transit Worker Protection.* Washington, DC: The National Academies Press. https://doi.org’10.17226/14657.

USDOT, Federal Transit Administration (2016). *State Safety Oversight*. Title 49 Code of Federal Regulations, Part 674.

USDOT, Federal Transit Administration (2017). Transit Advisory Committee for Safety (TRACS) 16-02 Final Report, *Safety Data and Performance Measures in Transit*. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-

[54] *Ibid.*

[55] *Ibid*.

guidance/safety/64016/safety-data-and-performance-measures-transit-tracs-16-02-final-report.pdf

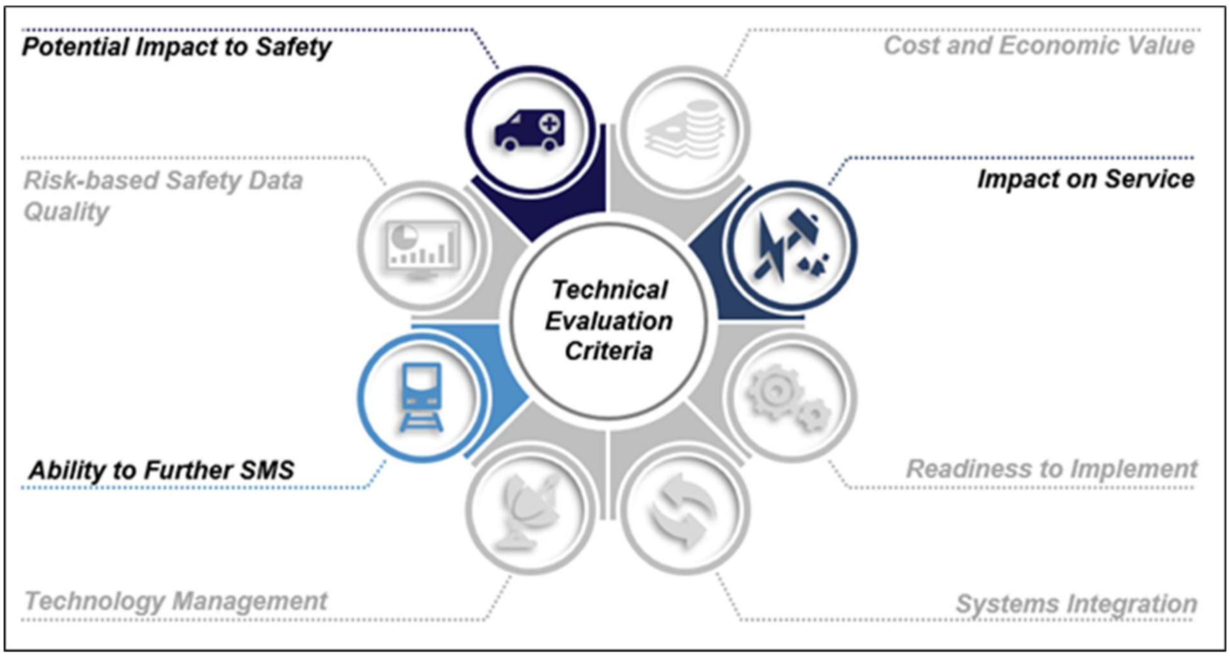
USDOT, Federal Transit Administration (2018). *Public Transportation Agency Safety Plans*. Title 49 Code of Federal Regulations, Part 673.

RWP Recommendation #6 – Fatigue Management for Maintenance, Controller, and other Non-Operating Personnel

Recommendation

The Committee recommends that FTA provide state-of-the art fatigue management guidance or research for all employees involved in roadway work, including track, signal, and structures maintenance workers, controllers, relevant supervisors, and other non-operator personnel not covered by fatigue management provisions such as hours-of-service limitations. Additionally, the Committee recommends that FTA establish safety performance standards and certification requirements in this area.

Criteria/Methodology



Criteria used to evaluate this recommendation include continuing effort to ensure that employees not only receive alerts to on-track vehicle movement, but that they themselves are alert enough to respond sufficiently to protect themselves from harm. Fatigue can be an insidious detriment to each roadway worker's personal safety, and fatigue can undermine the performance of safety-critical personnel such as controllers and supervisors.

The TRACS Report 14-02[56] provides considerable research and justification for fatigue management for operators, and also recommends that track maintenance, right-of-way and

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[56] USDOT, Federal Transit Administration (2015). Transit Rail Advisory Committee for Safety, Report 14-02, *Establishing a Fatigue Management Program for the Bus and Rail Transit Industry*. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/TRACS_Fatigue_Report_14-02_Final_%282%29.pdf.

signal inspectors, and supervisors be included in a second phase of fatigue management implementation. This Committee repeats those recommendations, noting that the FTA has not followed up with the previous Committee's recommendations. Due to the urgency of this matter, and the time lost, the Committee recommends that track maintenance, right-of-way and signal inspectors, and supervisors be included in any fatigue management system, and that the recommendations of the previous Committee be fast-tracked with this addition. TRACS believes the FTA has the authority to issue these standards, and the Committee encourages their implementation.

Key Takeaways

Takeaways

- All RTA personnel involved in roadway work and roadway worker safety must be alert.
- Fatigue is incompatible with the necessary level of alertness.
- Fatigue must be managed with the best practices available, such as described in the TRACS 2015 report on fatigue management.

Information Gaps

- Information on what the FTA has done to ensure fatigue management in general in RTA operations.
- Information on what fatigue management requirements exist for track maintenance, right-of-way and signal inspectors, dispatchers, controllers, and supervisors.
- A consistent framework is needed so that a guidance for SSOAs is not subject to multiple interpretations.

Additional Justification

Following a 2013 Chicago Transit Authority accident, the NTSB issued to the FTA the following recommendations related to this recommendation:

- Develop a work scheduling program for rail transit agencies that incorporates fatigue science—such as validated biomathematical models of fatigue—and provides for the management of personnel fatigue risks, and implement the program through the state safety oversight program. (R-15-18)
- Establish (through the state safety oversight program) scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements. (R-15-19)
- Require (through the state safety oversight program) rail transit employees who develop work schedules to complete initial and recurrent training based on

current fatigue science to identify and mitigate work schedule risks that contribute to operator fatigue. (R-15-21).

The Committee recommends that FTA provide an update of progress toward satisfying the NTSB's recommendations, and ensure that such fatigue management includes track maintenance, right-of-way and signal inspectors, dispatchers, controllers, and supervisors, and other non-operator personnel.

Conclusion

This recommendation should be implemented by FTA because it will provide safety protection to all roadway workers by addressing fatigue in those involved with roadway worker safety.

Reference Sources

Dembe, A., Erickson, J., Delbos, R., and Banks, M. (2005). The impact of overtime and long work hours on occupational injuries and illnesses: New evidence from the United States. *Occupational Environmental Medicine*, **62**(9), 588-597.

National Academies of Sciences, Engineering, and Medicine (2012). *TCRP Synthesis 95: Practices for Wayside Rail Transit Worker Protection.* Washington, DC: The National Academies Press. https://doi.org'10.17226/14657.

National Safety Council (2018). Fatigue in the workplace: Causes and consequences of employee fatigue. Part one of a three-part series. https://www.nsc.org/work-safety/safety-topics/fatigue/survey-report

National Safety Council (2018). Fatigue in the workplace: Risky employer practices. Part two of a three-part series. https://www.nsc.org/work-safety/safety-topics/fatigue/survey-report

National Safety Council (2018). Fatigue in safety-critical industries: Impact, risks, and recommendations. Final report of a three-part series. https://www.nsc.org/work-safety/safety-topics/fatigue/survey-report

National Transportation Safety Board (2014). *Chicago Transit Authority Train Collides with Bumping Post and Escalator at O'Hare Station, Chicago, Illinois, March 24, 2014.* Washington, D.C.: National Transportation Safety Board.

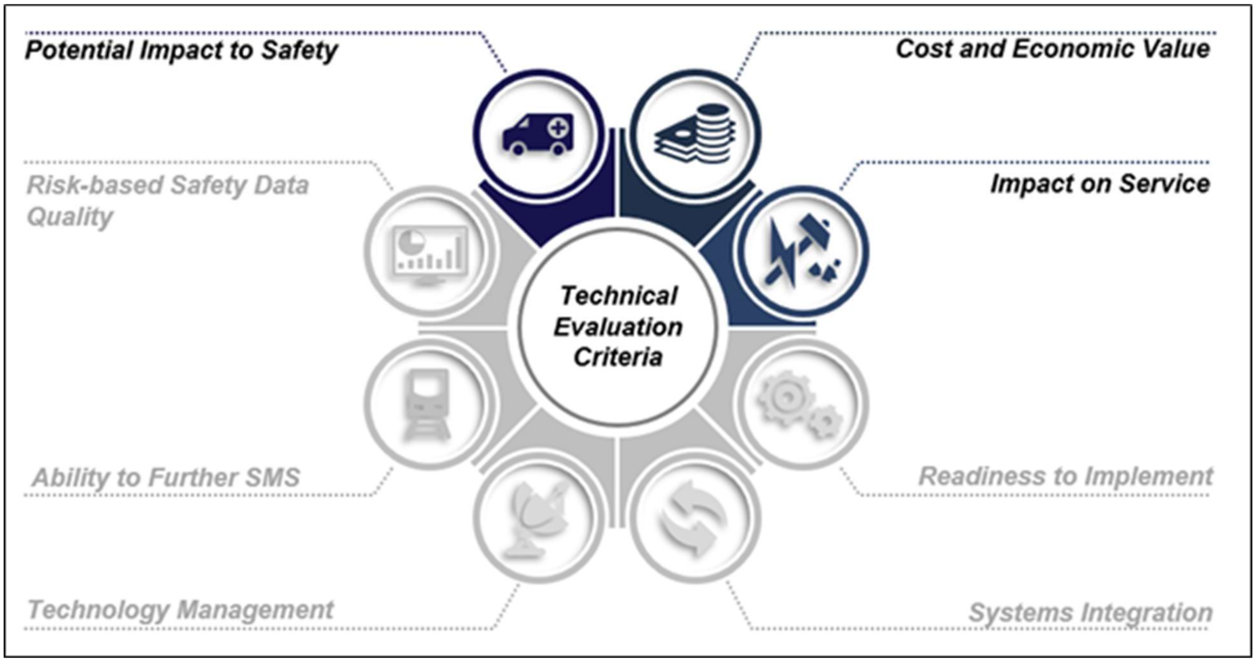
USDOT, Federal Transit Administration (2015). Transit Rail Advisory Committee for Safety, Report 14-02, *Establishing a Fatigue Management Program for the Bus and Rail Transit Industry*. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/TRACS_Fatigue_Report_14-02_Final_%282%29.pdf.

RWP Recommendation #7 – Research and Create Guidance on Cognitive Workload and Distraction of LRT Operators using In-Cab RWP Technology

Recommendation

The Committee recommends that FTA research and create guidance on the potential for cognitive workload and distraction of RTA operators caused by the use of in-cab RWP technology. The Committee recommends that FTA create guidance on ensuring that any added technologies and the added attentional, information processing, and decision-making demands created by their use will not create such an additional cognitive workload as to diminish employees' ability to attend to primary and other critical safety vigilance and response functions.

Criteria/Methodology



Criteria used to evaluate this recommendation include the potential impact to safety, cost/economic considerations, and the potential impact to service.

Human factors regarding electronic device use have been well researched in other modes of transportation including passenger vehicles and aviation.[57] A review of research literature shows that there has not been much research in the area of these human factors within transit

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[57] For a review see, California Public Utilities Commission, Consumer Protection and Safety Division (2009). *Personal Electronic Device Use on Rail Transit Systems: Report For R.08-10-007*. December 24, 2009. https://docs.cpuc.ca.gov/PublishedDocs/EFILE/RULINGS/111820.PDF

systems, and most that has been performed relates to bus transit.[58] With the implementation of new Roadway Worker Protection (RWP) safety technologies, it does not appear that any research has been performed to determine how such technology that involves in-cab indicators might affect an RTA operator's cognitive workload to process the additional input, and what types of distractions could be created by this new technology. However, it is clear from related research on driving that the potential for performance decrements should be investigated.[59] Additionally, the FRA has research publications that may provide assistance in applications of cognitive load and distraction to operator performance.[60] TRACS did not have the time or resources to review these publications, but recommends that future research and efforts to fill information gaps include thorough reviews of these articles - listed in the recommended reading below.

One important distinction between the bulk of electronic device driving distraction research, which is primarily on automobile drivers, is whether the technology-provided information is relevant to driving behavior. The vast majority of research is on cellphone use, which provides information almost entirely irrelevant to the driving task. In other words, the cellphone conversation is not about all the cues the driver must be attending to, and not about driving reactions and decisions. In contrast, RWP safety technology such as early warning systems with in-cab alerts or displays, is entirely relevant to critical operating cues, reactions, and decisions.[61] The addition of this new in-cab warning equipment does have a potential impact to safety. While the intent of the new in-cab warning equipment is to provide additional warning and protection for roadway workers, there is the potential that the new warning equipment could create a cognitive overload for the RTA operator causing the operator to be distracted from primary and other critical safety vigilance and response functions including watching for potential collisions with vehicles, bicycles, and pedestrians, or distracted from watching the speed at which the vehicle is being operated. Another possible potential impact to safety is operator complacency. It is possible that after a period of time once an operator becomes used to the warning equipment, the operator could possibly become complacent and not respond to the visual cues. And if the warning devices were to be activated too often, the operator may

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[58] See, for example, D'Souza, Kelwyn A., Siegfeldt, Denise V., Hollinshead, Alexa (2012). A Conceptual Analysis of Cognitive Distraction for Transit Bus Drivers. *1st National Conference on Intermodal Transportation: Problems, Practices, and Policy*, 63-78; and Nilsson, H., Mullaart, M., Strand, N., & Eriksson, A. (2020). The effects of information relevancy on driving behavior: A simulator study on professional bus drivers. *Cognition, Technology & Work*. Advance online publication. https://link.springer.com/article/10.1007%2Fs10111-020-00644-x

[59] See recent theory and research, Murphy, G., & Greene, C. M. (2017). Load theory behind the wheel; perceptual and cognitive load effects. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, 71(3), 191–202.

[60] See for example, US Department of Transportation, Federal Railroad Administration (2019). *Strategies to Manage Distractions*. Washington, DC. https://railroads.dot.gov/human-factors/elearning-attention/strategies-manage-distractions

[61] Nilsson, et al. (2020). *bid*.

just start tuning out these warning signals, thereby decreasing safety for the roadway workers the system is designed to protect.

The addition of this new in-cab warning equipment could have economic implications. For example, if operators are not able to cognitively adapt to the additional workload added by the new in-cab warning equipment, it could lead to a potential increase of events occurring on rail transit alignments. An increase of events could lead to an increase in maintenance and repair costs for rail transit vehicles.

In addition to a possible increase in events due to cognitive workload overload, the increase in events could also lead to a potential impact to service. With every accident that occurs, RTAs are required to perform an accident investigation, which takes time and impacts service. Additionally, the new in-cab equipment could also lead to unfair discipline because operators may not be able to adapt to the new warning equipment and experience cognitive workload overload. At worst this could lead not only to accidents, but to staffing shortages and possible reduction in service.

Key Takeaways

- Research should be completed regarding potential cognitive workload and distractions from attending to new RWP technology in operator cabs.
- Guidance on implementation of RWP technology to limit the possible impacts on operator cognitive workload and distraction should be a key part of implementation.

This recommendation addresses each of these two key takeaways. The committee recommends that FTA conduct research in this matter specific to light rail operator cognitive workload and distraction with any new in-cab RWP technologies. The committee also recommends that FTA create guidance on possible cognitive workload and distractions from using in-cab RWP technology in order to design training or mitigations for these hazards, if the research determines their existence.

Information Gaps

- Need for review of existing research in cognitive workload and distraction in transportation, including that of the FRA that might be relevant for use of RWP safety technology.
- Need for additional research specific to cognitive workload and distraction in general, and specific to RTA operators with in-cab RWP technology.
- Lack of guidance on training and mitigation of cognitive workload and distraction of RTA operators using in-cab RWP technology.

This recommendation addresses each of these information gaps. The committee recommends specific research on cognitive workload and distractions of RTA operators using in-cab RWP technology. Additionally, the recommendation addresses developing guidance on training and mitigation of cognitive workload and distraction of RTA operators using RWP technology in the operator car.

Additional Justification

The question remains: Will in-cab RWP safety technology cause extra cognitive workload and distraction? The lack of specific research answering this question may leave operations vulnerable to new safety issues rather than improved safety for RWP workers, thus being counterproductive to the purpose of developing new technologies to protect roadway workers. Further research on railroad reports must be reviewed to adequately understand this issue. Moreover, the rich history of cognitive overload's impact on safety should be cited as further justification for this recommendation.

Conclusion

This recommendation should be implemented by the FTA because it will provide the necessary research and development of guidance for training and mitigation of cognitive workload and distraction of RTA operators using in-cab RWP technology.

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Gillis, I., JR Wilson, B Norris, T. Clarke 2007. *People and Rail Systems: Human Factors at the Heart of the Railway.* London: Lawrence Erlbaum.

McLeod, R.W., G.H. Walker, N. Morray 2005. *Analyzing and Modelling Train Driver Performance.* Glasgow, Scotland: Applied Ergonomics.

Murphy, G., & Greene, C. M. (2017). Load theory behind the wheel; perceptual and cognitive load effects. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, 71(3), 191–202.

Nilsson, H., Mullaart, M., Strand, N., & Eriksson, A. (2020). The effects of information relevancy on driving behavior: A simulator study on professional bus drivers. *Cognition,* *Technology & Work*. Advance online publication. https://link.springer.com/article/10.1007%2Fs10111-020-00644-x

Recommended Reading[62]

Grice, R. (2020). *Heads-up display to reduce distraction for locomotive engineers (Work in-progress)*. Washington, DC: USDOT, FRA. https://railroads.dot.gov/human-factors/ctil/browse-research

Sebok, A., Haggit, J., and Gacy, M. (2020). *Evaluation of automation-induced human error in the locomotive cab (Work in-progress).* Covington, KY: Tier 1 Performance Solutions. https://railroads.dot.gov/human-factors/ctil/browse-research

Sebok, A. (2017). *Investigating human-automation interaction and human error in the locomotive cab*. McLean, VA: Alion Science and Technology. https://railroads.dot.gov/sites/fra.dot.gov/files/fra_net/17995/008-PS-2017.pdf

US Department of Transportation, Federal Railroad Administration, Office of Railroad Policy & Development (2017). *A Preliminary design for a heads-up display for rail operations, RR 17-08.* Washington, DC: USDOT, FRA. https://railroads.dot.gov/sites/fra.dot.gov/files/fra_net/17178/Locomotive_HUD_final.pdf

US Department of Transportation, Federal Railroad Administration (2013). *Using Cognitive Task Analysis to Inform Issues in Human Systems Integration in Railroad Operations.* Washington, DC: USDOT, FRA. https://rosap.ntl.bts.gov/view/dot/9939/dot_9939_DS1.pdf?

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US Department of Transportation, Federal Railroad Administration (2019). *Strategies to Manage Distractions*. Washington, DC: USDOT, FRA. https://railroads.dot.gov/human-factors/elearning-attention/strategies-manage-distractions

US Department of Transportation, Federal Railroad Administration (2020). *Cab Technology Integration Laboratory (CTIL) Overview.* Washington, DC: USDOT, FRA. CTIL is located and operated at the Volpe National Transportation Systems Center (the Volpe Center). https://railroads.dot.gov/CTIL See also, https://railroads.dot.gov/human-factors/ctil/reports-presentations

Yang, G., Ahmed, M., and Subedi, B. (2020). Distraction of connected vehicle human–machine interface for truck drivers. *Transportation Research Record: Journal of the Transportation Research Board*.

[62] Some of these research pieces were works in-progress at the time of the writing of this report, but may be completed by the time the reader gets this report.

RWP Recommendation #8 – Behavior-Based Safety Systems for RWP

Recommendation

The Committee recommends that FTA research the existing behavioral focused safety initiatives and literature for application to RWP in particular and to safety culture and Safety Management Systems (SMS) effectiveness in general.

The Committee recommends that FTA create guidance for utilizing behavior-focused interventions that identify conditions necessary for their successful inclusion in holistic organization efforts to improve safety culture and the effectiveness of SMS. The guidance should draw on research on such programs as behavior-based safety (BBS), the FRA's Clear Signal for Action (CSA), Union Pacific's Changing At-Risk Behavior (CAB) and Safety through Employees Exercising Leadership (STEEL), and Amtrak's Employee Alliance for Great Levels of Excellence in Safety (EAGLES). The Committee believes that when considering SMS modeling, this is the core component of safety culture. It also correlates to non-punitive employee safety reporting (ESR) as a means of developing safety culture.

The guidance should present the basic features of successful interventions, such as constructive feedback; timeliness of feedback; peer-to-peer feedback; feedback needing to be accepted and perceived as positive and constructive, ensuring management's genuine belief, buy-in, and implementation of the basic principles; training and education; and the necessary rapport with employees.

The guidance should present and explain the basic psycho-social-organizational research evidence that underlies these behavior-change/maintenance systems, such as the principles of behavior modification, the fundamental attribution error,[63] similar-to-me biases,[64] root-cause analysis, procedural fairness, and perceptions of fairness.

The guidance should also describe how such interventions should be integrated with other interventions such as non-punitive safety reporting systems and SMS.

The guidance should focus on how it relates to the use of RWP safety technology.

Given the importance of this topic more generally to safety culture improvement and SMS and the limited time and resources of the 2018-2020 TRACS effort, the Committee recommends that this topic be one of the tasks for the 2020-2022 TRACS as more generally applied to transit safety.

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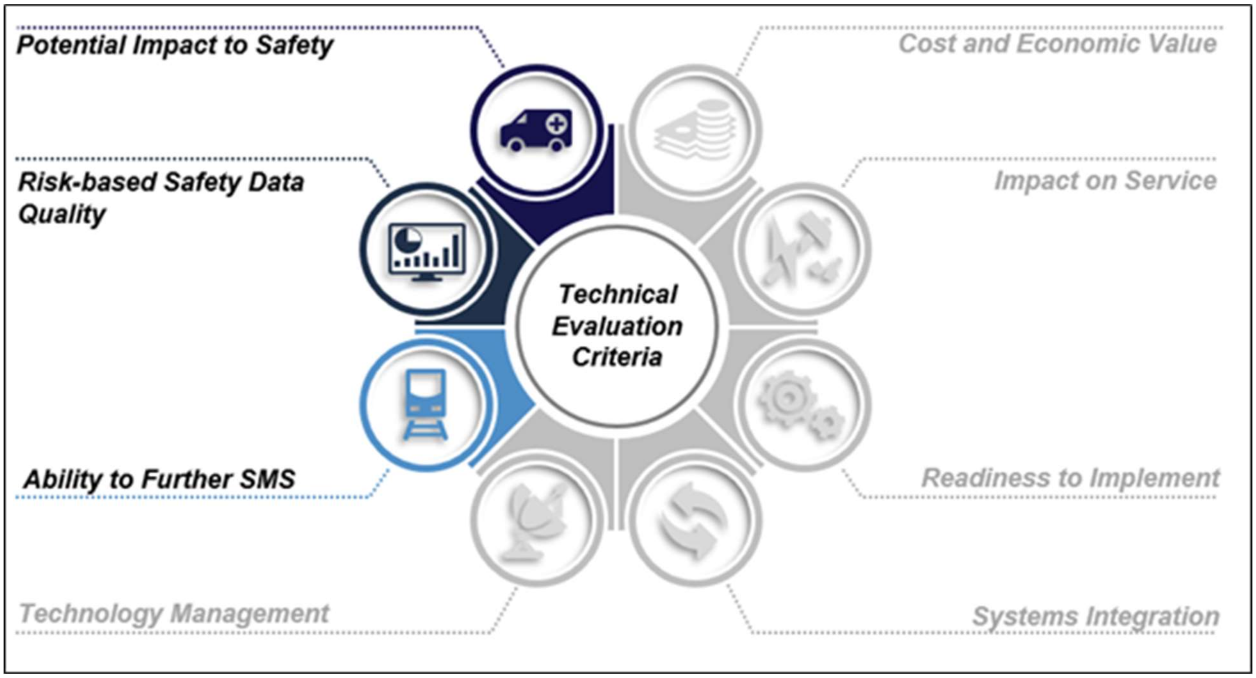
[63] Discussed in detail below in this recommendation.

[64] Wexler, K., Alexander, R., Greenwalt, J., & Crouch, M. (1980). Attitudinal congruence and similarity as related to interpersonal evaluations in manager-subordinate dyads. *Academy of Management Journal*, **23**, 320-330.

Criteria/Methodology



It is clear that behavior is the basis of safety. While attitudes and beliefs affect behavior, it is the resulting behavior that is either safe or not, improves safety culture or not, and advances SMS or not. The ultimate criterion for any system is whether it reduces casualties. However, prevention strategies must look at those behaviors that lead to casualties, and ensure that they are redirected, controlled, or modified so that safety is achieved. Thus, both lagging and leading indicators should be studied as criteria for any behavior intervention effort.

Lagging indicators can tell us the effectiveness of an intervention in the long-term. The principles involved in statistical significance indicate that small numbers, i.e., low rates of events such as fatalities, require longer timelines before conclusions can confidently be made. In contrast, leading indicators can provide more data simply due to the increased number of observations of behavior available, and assessments of any increase in safe behavior.

Key Takeaways

Takeaways

- RWP safety depends on the behaviors of individuals, both at the person level and collectively.
- Psychological science provides considerable evidence that positive reinforcement produces behavior change more successfully than traditional railroad supervisory methods based on disciplinary punishment.

- Field studies on U.S. railroads, sponsored by the Federal Railroad Administration, have demonstrated considerable improvement in desired behaviors and the reduction of casualties.[65]
- Rail transit agencies under the purview of the FTA would benefit from such applied behavior science, including behavior-based safety interventions, and in particular would improve behaviors relating to roadway worker protections.
- In the transit industry, investigations into rules compliance often ignore the actual causes of employees' behavior. Quality root cause analyses can reveal the behavioral underpinnings of errors and mistakes that are precursors of actual events, including fatal incidents.

Information Gaps

- The Committee does not have program-level detail on how behavior-based safety programs are implemented and maintained.
- The Committee does not have information on a full inventory of behavior and psychological science relating to behavior-based safety and its potential role in safety culture and safety management systems.
- The Committee does not have sufficient information and analysis to produce any final report on the application of behavior-based safety in the rail transit industry.

Additional Justification

Considerable behavioral and psychological research is available on the efficacy of positive reinforcement, especially in contrast to disciplinary punishment. Related psychological research, such as on the *fundamental attribution error*,[66] will assist in implementing positive reinforcement systems by explaining how positive reinforcement systems work, for example, how misattributions that lead to blaming and discipline can be counterproductive.

The *fundamental attribution error* has been established in the psychological research literature as the tendency to attribute the cause of an individual's behavior to that individual's disposition, or in other words, the individual alone caused the behavior. This attribution is

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[65] U.S. Department of Transportation, Federal Railroad Administration (2007). *Behavior-based safety at Amtrak-Chicago associated with reduced injuries and costs*. Research Results, RR07-07, Washington, DC., and U.S. Department of Transportation, Federal Railroad Administration (2009). *Improved safety culture and labor-management relations attributed to changing at-risk behavior process at Union Pacific*. Research Results, RR09-19, Washington, DC.

[66] *See*, *for example*, Ross, L. (1977). "The intuitive psychologist and his shortcomings: Distortions in the attribution process". In Berkowitz, L. (ed.). *Advances in experimental social psychology*. **10**. New York: Academic Press. pp. 173–220. *See also*, Geller, E. Scott (2000). The Psychology of Safety. Boca Raton, FL: CRC Press, pp. 102-104, and Reason, J. (1997). *Managing the risks of organizational accidents.* Aldershot: Ashgate, pp. 126-127, 231.

termed an error because it neglects to account for the holistic nature of cause, ignoring environmental conditions, and training, reward systems - all those conditions external to the individual that influence behavior. One explanation is that we see the actions of the individual, but do not see his or her past history, the physical and temporal conditions leading to the event, and given the circumstances, any capacity to have acted otherwise. The error is at the root of a "blaming culture." The error's occurrence has been especially supported by evidence from negative events such as accidents,[67] and as such contributes to misconceptions of "accident proneness." The error is complicated by the statistical fact that under conditions of pure randomness, relatively rare events such as accidents will accrue disproportionately to some individuals - with no differences in behavior or circumstances.[68] The attribution that individuals with more accidents are accident-prone can not only ignore differences in external events beyond an individual's control, but can also simply be a statistical illusion. Behavior-focused programs and studies can not only improve safety, but can also lead to metrics that provide process standardization that reduce risks and employee injuries.

Conclusion

There is sufficient evidence that behavior-based safety programs are effective in soliciting optimal behaviors needed for safety in rail transportation systems. FTA's next iteration of TRACS should include a task for implementation of such systems on the RTAs under FTA purview. That research should also address evidence from the behavioral and psychological sciences that complements behavior-based safety system implementation. Additionally, evidence from non-punitive reporting systems shows the benefits of avoiding disciplinary punishments in advancing safety behaviors and safety culture.[69]

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[67] Malle, Bertram F. (2006). The actor-observer asymmetry in attribution: A (surprising) meta-analysis. *Psychological Bulletin*. **132** (6), 895–919.

[68] McKenna, Frank P. (1983). Accident Proneness: A conceptual analysis. *Accident Analysis and Prevention*. **15** (1), 65-71, for statistical explanations for misconceptions of accident proneness.

[69] See Transit Rail Advisory Committee for Safety (TRACS) Working Group 11-01 Report (2012) *Establishing a Confidential, Non-Punitive, Close Call Safety Reporting System for the Rail Transit Industry*. https://www.transit.dot.gov/regulations-and-guidance/safety/close-call-safety-reporting-11-01.

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Appendices

A – 1 TRACS Conferences

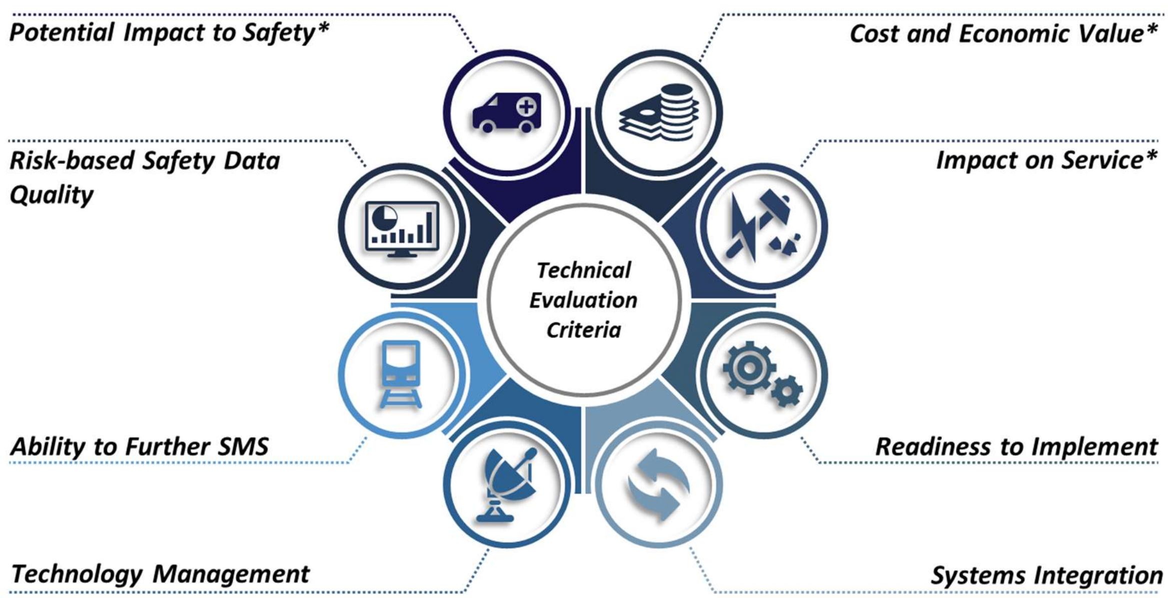
March 26-27, 2019 Conference

Goals and Objectives

In March of 2019, the 2018-2020 TRACS met for the first time and focused on defining the tasks from FTA. FTA assigned the Committee the safety focus area, TSP, and requested the selection of two additional safety focus areas. To help define the additional safety focus areas, FTA produced a list of 25 potential topics for the Committee to consider. Through a series of breakout groups and large group discussions, the Committee voted to select RWP and ESR. Through a voting process, the Committee selected and prioritized a list of technology evaluation criteria (TEC), which were used to evaluate emerging technologies and innovative processes to inform the Committee's recommendations.

Outcomes

During the March 2019 TRACS Conference, the Committee identified and prioritized TEC that apply to all three safety focus areas identified by the 2018-2020 Charter. TEC were established to support the assessment of technologies and innovations and were selected based on small- and large-group discussions. TEC are as follows:



An asterisks (*) represents the high priority technical evaluation criteria

The Committee identified three TEC as high priority, the first of which is *Potential Impact to Safety*. *Potential Impact to Safety* was used to evaluate the technologies and innovations on the basis of FTA's four safety performance measures identified in FTA's National Public

Transportation Safety Plan: fatalities, injuries, safety events, and system reliability.[70] Fatalities and injuries represent "lagging indicators," which support the assessment of long-term success *after* an intervention. This assessment is done by monitoring negative safety outcomes that agencies aim to prevent. Precursor safety events and system reliability declines are examples of "leading indicators," which help predict the success of an intervention *before* it is implemented. As such, leading indicators are essential to evaluating emerging technologies. TRACS has consistently addressed both lagging and leading indicators in its safety reports.[71] It is also important to note that leading indicators can address near-miss reports, known risks of automation use, opportunities for failure, and other risk-informing knowledge where no casualties have been documented on rail transit.

The other criteria deemed high priority were *Cost and Economic Value* and *Impact on Service. Cost and Economic Value* includes multiple factors, such as short versus long term costs, return on investment, affordability, integration costs, and maintenance costs. The Committee also considered the *Impact on Service* for new technologies and processes. For example, if a technology is extremely beneficial in preventing accidents but significantly decreases the number of trains running per hour, it may not be a viable solution.

While *Potential Impact to Safety*, *Cost and Economic Value*, and *Impact on Service* were deemed the highest priority criteria for evaluating technology, the Committee selected additional TEC to consider. *Readiness to Implement* is a technology's maturity level and whether it is compatible with existing systems. Similarly, the Committee deemed it important to look at *Systems Integration*, which evaluates technology from the viewpoint of how it would complement information technology, training requirements, and human factors/engineering considerations. Additionally, the Committee considered *Technology Management*, which involves maintenance requirements and the introduction of unforeseen risks.

Moreover, the Committee acknowledged that the implementation of a SMS approach is paramount to FTA's overall safety focus, as it is a collaborative approach to managing safety that brings management and labor together to control risk, detect and correct safety problems earlier, analyze safety data more effectively, and measure safety performance more precisely. Therefore, the Committee supported the recommendation of technologies and processes that promote the transit industry's shift toward furthering SMS. The Committee also recognized the increased importance that data has in the transit industry's environment and will consider how effective measuring and monitoring methods rely on obtaining and analyzing *Risk-based Safety Data Quality*.

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70 Federal Transit Administration. (2017). *National Public Transportation Safety Plan*. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/National%20Public%20Transportation%20Safety%20Plan_1.pdf

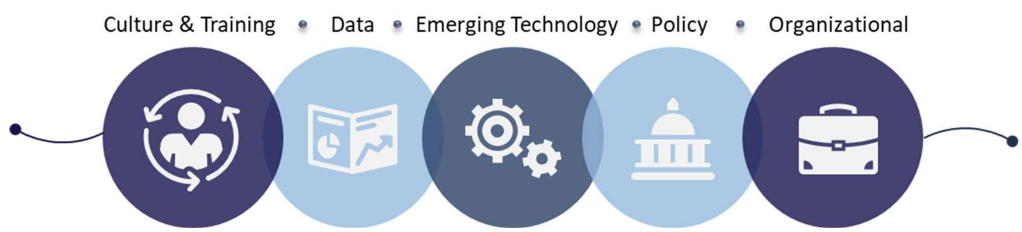
71 *See* Transit Advisory Committee for Safety (TRACS) 16-02 Final Report. (2017, March). *Safety Data and Performance Measures in Transit*. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-guidance/safety/64016/safety-data-and-performance-measures-transit-tracs-16-02-final-report.pdf.

Finally, the Committee recognized that transit agencies possess their own set of unique characteristics related to mission, size, operational practices, budget constraints, and so forth. The Committee considered these variables and agreed it would maintain the TEC as its primary driver for developing the Committee's recommendations.

September 9-10, 2019 Conference

Goals and Objectives

Through a literature review and multiple group discussions, during the September Conference, TRACS identified an extensive list of key takeaways and information gaps that will contribute to the Committee's recommendations for FTA. These key takeaways and information gaps were grouped into the following five themes or categories, which were consistently found in the research:[72]



The *Culture and Training* category reflects how societal and organizational cultures influence decision-making and safety. Additionally, it looks at how education can be leveraged to benefit culture. Through a review of *Emerging Technology*, the Committee sought to explore different technologies and how they can be/are being used to prevent trespassers and suicide attempts, increase safety for roadway workers, and improve employee safety reporting programs. The *Emerging Technology* theme assesses the various emerging technologies to see where and how each innovation will have the most impact. The *Policy* theme seeks to understand what is needed for developing successful rules and regulations. Policy can be looked at from an internal organizational perspective or an external governing body perspective. On a similar note, the *Organizational* theme seeks to understand the impact that specific organizations or differences between organizations can have on understanding different components of the safety focus area. Finally, by looking at *Data*, the Committee hopes to understand how information is compiled, analyzed, and used, and how systems could be improved to better understand the circumstances and environments in which trespass events and suicide incidents occur. Additionally, TRACS considered how *Data* can be used to apply value that comes from employee safety reporting programs.

Outcomes

Emerging Technology

Key Takeaways

The Committee reviewed multiple RWP safety technologies that are currently available to the industry and being used by Rail Transit Agencies (RTAs). Understanding RTA experiences using

[72] Note that none of the safety focus areas address key takeaways/information gaps in all five categories.

these technologies could help clarify which technologies have been successful. Additionally, the Committee noted that independent redundancies are essential components of RWP technologies and innovations, as they prevent the potential for single-point failures. To expand on this, while technologies are extremely valuable, they should not be the only form of train-to-worker protections and should be used as secondary protections; technology is another layer that helps ensure safety beyond effective RWP protections.

Information Gaps

The information gaps associated with emerging technology can help uncover additional information and research that TRACS can use to make concrete and viable recommendations to FTA. Primarily, the Committee identified a need to gather additional information on newer technologies that are available to the transit industry, how they are being used, where they are working, where they are not working, and why they work or do not work. While many new technologies exist, the Committee is unclear about product feasibility and whether these new technologies can be implemented in a reasonable and practical way. Feasibility and practicality present issues such as perspective, operational ease of use, employee acceptance, and maintenance.

Additionally, the Committee expressed concerns about the complexities of innovative technologies, recognizing that there needs to be a greater understanding of the maturity and flexibility of these technologies. For example, considerable research on instances where automation has been introduced into transportation systems, especially in aviation, has highlighted failures in interactions between humans and automation. Over-reliance on automation where human visual cues would have otherwise been used, have resulted in transportation accidents in some cases.[73]

Policy

Key Takeaways

The Committee explored the increased growth and desire for more technology and innovative solutions for RWP which will require additional training, new rules, and standards to keep pace with the demand. A robust library of voluntary standards for roadway worker safety already exists, but there is an opportunity for FTA to revisit and re-establish SSOA requirements and oversight. The Committee also referenced FRA's RWP rule-making process and ways to integrate the process into the new recommendations.

Information Gaps

The Committee identified several information gaps from a policy perspective. First, the Committee recognized the need for more data and research, particularly as it pertains to the work FTA has conducted following the NTSB's RWP recommendations and FTA's Safety Advisory 14-1. Additional information is also needed on the effects of this work on policies and

[73] *See* Mosier, K. L. and Skitka, L. J. (1999). Automation use and automation bias. Proceedings of the *Human Factors and Ergonomics Society 43rd Annual Meeting*, September 27 to October 1, Houston Texas. *See also* Noy, I., Shinar, D., & Horrey, W. (2018). *op cit*.

operations. Second, given a lack of information, the Committee is unable to determine which training tools exist that may provide opportunities for innovation. Additionally, there is a need to establish a clear and consistent definition for redundant protection, as multiple definitions or terms can result in skewed or inconsistent data, research, and proposed solutions.

Organizational

Key Takeaways

The Committee noted that RWP technologies are not universally applicable or scalable, so geographical and demographic differences across RTAs (e.g., size, mode, budget) need to be considered when looking at the data and research. Additionally, industry and the public sector should consider the delicate balance of increased safety and the ability to sustain high tempo operations. This is particularly essential for older systems to ensure that they run safely, smoothly, and efficiently. Finally, an emphasis on positive safety behavior and culture is critical for the successful implementation of RWP technologies and innovation. The Committee extensively discussed the need to incorporate concrete safety culture enhancements, such as non-punitive safety reporting systems and BBS into their RWP recommendations.

Information Gaps

From an organizational lens, the Committee identified several information gaps for RWP. It is unknown how RWP and the implementation of RWP technologies can be successful within an SMS framework and further research is needed in this area. Additionally, the industry is lacking clarity about the integration of protections and standards into an SMS framework and what changes may be necessary to bridge any gaps between SMS and RWP policy and standards. Finally, the delicate balance of system use with system operations and efficiency needs to be carefully considered. Older systems that have undergone years of use, growth, and expansions present a challenge to RWP because they require increased operational attention and have high-maintenance demands. Increased maintenance demands will require more time spent working in the right-of-way, which creates more opportunities and scenarios for accidents to occur.

February 25-26, 2020 Conference

Goals and Objectives

The conference objectives were as follows:

- Assess emerging technologies and processes against TEC.
- Assess industry posture.
- Begin development of recommendations.
- Refine work plans for remainder of the 2018-2020 TRACS Charter.

Outcomes

During the February Conference, the Committee continued its work towards accomplishing its assigned task through research review and breakout group discussions covering the three safety focus areas approved by FTA. The agenda included a review of the TRACS tasking, work plan, and selected safety focus areas; an assessment of emerging technologies and processes against TEC identified during the March 2019 TRACS Conference; presentations on relevant research topics and technologies; public comments; and voting on decisions requiring consensus. An overview of the presentations is included in section A-3 of this Appendix.

July 21-22, 2020 Conference

Goals and Objectives

The July Conference objectives were for the TRACS subcommittees (RWP, ESR, and TSP) to present and discuss recommendations to be voted on for inclusion in the final TRACS reports submitted to FTA.

Outcomes

The Committee discussed all recommendations, provided feedback on recommendations, and unanimously approved all eight RWP recommendations, all four ESR recommendations, and all seven TSP recommendations, with some recommendations requiring updates in advance of the final vote of approval on the final reports.

A – 2 Recommended Literature

The RWP subcommittee performed a limited literature review of journal articles and reports to inform the recommendations and also identified additional articles and publications relevant to the RWP topics herein. To facilitate further progress on this topic, TRACS recommends the following reference and reading list, which includes both reviewed and identified sources:

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A – 3 Research Presentations

March 2019 Conference	
Presenter(s)	**Topic**
Michael Coplen	TRACS Legislative/Rulemaking Update
Lisa Staes	Safety Data Analysis
Lisa Staes	Risk Based Analysis
Lisa Staes	Safety Risks and Potential Mitigations

September 2019 Conference	
Presenter(s)	**Topic**
Dr. Scott Gabree	Trespass and Suicide Prevention
Dr. Jordan Multer	Employee Safety Reporting

February 2020 Conference	
Presenter(s)	**Topic**
Dr. Pei-Sung Lei	FTA Standards Program Research: Mitigations for Trespasser and Suicide Fatalities and Injuries
Ben Bakkum and Dr. Dingqing Li	Roadway Worker Protection
Lisa Staes	Secondary Roadway Worker Protection Systems
Lisa Staes	Employee Safety Reporting Research Presentation
Michael Coplen	Behavior Based Safety (BBS) Presentation
Vendor Presentations: METROM-RAIL, Miller Ingenuity, Bombardier, EMTRAC, Trapeze Group, Protran, Hotrail Group, Motorola Solutions/Avigilon Video Security and Analytics	Vendor Presentations on RWP and TSP Technologies

Additional Presentations	
Presenter(s)	**Topic**
Hilary Konczal	Trespasser and Suicide Prevention Strategies
Dr. Richard Gist	Impact of Critical Incidents (CI) on Involved Train Crews
Dr. Paul King	BBS Studies/Articles written by Scott Geller

A – 4 Roadway Worker Fatalities Investigated – 2000 through 2008[74]

CALIFORNIA

Three roadway workers have been fatally injured on California rail transit agency properties since 2001. The accidents are:

- Bay Area Rapid Transit District fatality on October 14, 2008.
- Sacramento Regional Transit District fatality on July 24, 2008.
- Bay Area Rapid Transit District fatality on January 12, 2001.

In each of these fatal accidents [CPUC] Staff identified inadequate roadway worker protections as a contributory factor.

BAY AREA RAPID TRANSIT DISTRICT

BART'S OCTOBER 14, 2008 FATAL ROADWAY WORKER ACCIDENT

A BART train struck and fatally injured a BART structures inspector while he was inspecting the fence along the BART right-of-way on October 14, 2008, as part of a two-man crew. The inspectors had requested and received a "Simple Approval" authorization from the control center to enter a restricted area consistent with existing BART rules and procedures. Simple Approval allows inspectors to access trackways with their own vigilance for approaching trains as their only protection. (Discussed further in the Discussion section later in this report.)

Probable Cause

[CPUC] Staff has determined that the reliance on Simple Approval procedures and failure to comply with BART rules are the most probable causes of this accident.

Contributing Cause Factors

Additional contributing factors to this fatal accident were:

- No lookout or flagperson was watching for approaching trains.
- Additional roadway workers were performing work on the adjacent track without knowledge and/or coordination with the structures inspectors.
- Trains were operating in single-track mode, taking turns operating on one track in opposing directions rather than in the usual and customary method of opposing trains operating on separate tracks. The Structures Inspectors were unaware of single-track operations.
- The toe path (walkway) adjacent to the right-of-way was partially obscured by overgrown vegetation which may have caused the victim to walk into the trackway and may have diminished the train operator's field of vision.
- No other technology was in use to warn roadway workers at the time of the accident.

[74] Excerpted from California Public Utilities Commission, Consumer Protection and Safety Division (2010). *Roadway worker protection on California rail transit systems: Consumer Protection and Safety Division Report for R.09-01-020*, pp. 6-15. https://docs.cpuc.ca.gov/PublishedDocs/EFILE/RULINGS/113001.PDF

- The structures inspector failed to comply with BART's rule which requires that inspector set his/her portable radio to "scan" mode to monitor communications between trains, control operators, and/or other roadway workers.
- BART's policy of allowing roadway workers to use personal cell phones as a means of communication between themselves, permits these workers to become distracted from the job being performed, a policy which may also effectively circumvent the BART rule to set portable radios to scan mode.
- The structures inspector was wearing a safety vest at the time of the accident, but it was not the required safety vest mandated in BART rules and procedures. Reenactment of the accident findings revealed that the BART-approved safety vest provides a slight improvement with regard to the visibility of the wayside workers.
- BART did not have a compliance testing or safety rules testing program to ensure workers' compliance with roadway safety rules and procedures.

[CPUC] Staff further determined that BART does not have a program to collect, review, or develop corrective action plans for near-collision and/or near-hit reports from roadway workers. Although BART does have an existing requirement that each "unusual occurrence" — such as an accident, disturbance, irregularity, or rule/procedure violation which might affect service or involve or threaten injury to persons or damage to equipment on BART Property — be documented on an Unusual Occurrence Report, this requirement does not specifically require roadway worker near-hit reporting.

BART'S JANUARY 12, 2001 FATAL ROADWAY WORKER ACCIDENT

A BART electrician was struck and fatally injured by a BART train on January 12, 2001. The electrician was on the fourth day of his assignment in this capacity and was part of a two-man crew. The crew was walking between the rails and the wall inside a tunnel to investigate a report of a small fire on the track. The electrician was struck while facing the track with his back against the tunnel wall. The workers were authorized to be working on the trackway with Simple Approval authority. The surviving crewmember stated he only had a few seconds to position himself safely against the tunnel wall and yell to the other crewmember to get out of the way before the train arrived. The tunnel has insufficient clearance for a person to stand along the wall while a train passes at the location where the roadway worker was struck by the train.

Probable Cause

The accident investigation report identified the most probable cause of this accident as the failure of the wayside maintenance crew to detect the approaching train and move to a safe location prior to its arrival.

Contributing Cause Factors

Contributing factors include the ambient noise from the approaching train and the sound from the ventilation fans, inattentiveness to surrounding conditions, reliance on Simple Approval rules, and the victim's inexperience with the work environment.

SACRAMENTO REGIONAL TRANSIT DISTRICT

SRTD'S JULY 24, 2008 FATAL ROADWAY WORKER ACCIDENT

A Sacramento Regional Transit District (SRTD) train struck and fatally injured a wayside maintenance worker just east of the Watt/I-80 West Station in Sacramento, California, on July 24, 2008. The train was operating normally in manual mode with no reported defects. The weather was sunny and clear and the view ahead was unobstructed. The wayside worker had walked to a point on the track between the rails with his back to the train when it was stopped approximately 260 feet away at the station platform, and was struck by the train as it left the station. [CPUC] Staff concluded from the operator's interview and the train's video recordings, that neither the wayside worker nor the train operator saw each other. The wayside worker was focused on lubricating the track and the train operator had just received two text messages as the train departed the station and had been frequently using her cell phone during the trip.

Probable Cause

[CPUC] Staff has determined the most probable causes of this accident were:

- The requirement for the wayside worker to simultaneously attend to work tasks and approaching trains.
- SRTD's inadequate safety protection procedures, choices, and rules applicable and available to wayside workers.
- The wayside worker's choice of an inadequate level of protection, and his failure to detect approaching trains and move away from the track.
- The train operator's inattention to duties from use of her personal cell phone while operating the train.

Contributing Cause Factors

Additional contributing factors to this accident included:

- Absence of a program to collect, review, and develop corrective action plans for near-collisions and/or near-hit reports.
- Inadequate rules compliance testing of train operators.
- Lack of a rules compliance testing program for wayside workers.
- Setting working distance limits of approximately 6.5 miles in length for wayside workers. These long distances do not focus train operators' attention on the specific areas where workers are working at any one time, and likely decrease operator's ability to be sufficiently vigilant.
- Possible conflicting workload and scheduling incentives that may interfere with the choice of safe protection by wayside workers. Workers may be incented to choose protections that minimize schedule impacts but which do not maximize personal safety.
- Possible train operator inattention to duties from personal conversation with another SRTD employee on-board the train.

GEORGIA

The Metropolitan Atlanta Rapid Transit Authority (MARTA) fatal roadway worker accidents:

- MARTA'S fatalities on April 10, 2000.

- MARTA'S fatality on February 25, 2000.

MARTA'S APRIL 10, 2000 FATAL ROADWAY WORKER ACCIDENT
An unscheduled MARTA train struck the bucket of a self-propelled lift that was fouling the southbound main track at MARTA's Lenox Station, in Atlanta, Georgia, on April 10, 2000. Two MARTA contract workers who were repairing the station ceiling from the lift bucket were fatally injured when they were thrown from the bucket to the station platform.

Probable Cause
The NTSB determined that the probable cause of the accident was MARTA's failure to require use of single-tracking safety procedures to protect the work site and the failure of the rail system control center assistant superintendent and the flagman to follow all MARTA safe clearance procedures for protecting workers fouling the track.

Contributing Cause Factors
The NTSB also determined that MARTA's lack of an effective program to ensure that employees were complying with its safety rules contributed to the accident.

MARTA'S FEBRUARY 25, 2000 FATAL ROADWAY WORKER ACCIDENT
An eastbound MARTA train struck two automatic train control technicians who were inspecting signal equipment on the main track in Decatur, Georgia on February 25, 2000. One of the technicians was killed and the other sustained serious injuries. The technicians had not placed flagging devices to warn train operators of their presence and had not placed shunts on the rail to activate the signal system warning approaching trains. The technicians also failed to request a safe clearance restriction from the operation control center for the inspection.

Probable Cause
The NTSB determined the probable cause to be the failure of MARTA to ensure that written safe clearance procedures were followed for employees doing inspections on the right-of-way.

Contributing Cause Factors
Although not mentioned in the NTSB's Accident Report, the roadway workers' failure to place flagging devices and/or shunts and their failure to request a safe clearance restriction contributed to the accident.

ILLINOIS
CHICAGO TRANSIT AUTHORITY'S FEBRUARY 26, 2002 WORKER ACCIDENT
A Chicago Transit Authority (CTA) Green Line train struck two signal maintainers in the Chicago Loop on the night of February 26, 2002. One maintainer fell from the elevated loop structure onto a parked automobile and was seriously injured. The signal maintainers failed to place flashing yellow lights to warn train operators of the track work as required by CTA rules. CTA did not have any written procedures requiring that a safety lookout be designated.

Probable Cause

The NTSB determined that the probable cause of the accident was the failure of the signal maintainers to watch for approaching trains and their failure to obey the CTA's rule that they increase their visibility by displaying a flashing yellow warning light.

Contributing Cause Factors
The NTSB further found that contributing to the maintainers' reduced awareness of oncoming trains was the absence of clear requirements regarding the designation of safety lookouts and the use of interlocking signals to protect work areas.

THE MASSACHUSETTS BAY TRANSPORTATION AUTHORITY'S (MBTA'S) FATAL ROADWAY WORKER ACCIDENT OF JANUARY 9, 2007.
A southbound Massachusetts Bay Transportation Authority passenger train operated by the Massachusetts Bay Commuter Railroad struck a track maintenance vehicle performing track work on January 9, 2007. Six maintenance-of-way employees were working on or near the track maintenance vehicle. Two employees were killed and two were seriously injured. The accident caused significant service interruption. Property damage was also substantial, with the estimated damages to track and equipment totaling over $500,000.

Probable Cause
The NTSB determined that the probable cause of this accident was the failure of the train dispatcher to maintain blocking that provided signal protection for the track segment occupied by the maintenance of way crew, and the failure of the work crew to apply a shunting device that would have provided redundant signal protection for their track segment.

Contributing Cause Factors
The NTSB found the Massachusetts Bay Commuter Railroad's failure to ensure that maintenance-of-way work crews applied shunting devices as required was a contributing factor to the accident. Finally, the NTSB found that maintenance-of-way crews on all railroads who depend on the train dispatcher for signal protection need redundant protection (e.g., shunting devices) to restrict train movements into work areas.

NEW YORK
New York City Transit's (NYCT's) fatal roadway worker accidents:
- NYCT's fatality on April 24, 2007
- NYCT's fatality on April 29, 2007

NYCT'S APRIL 24, 2007 FATAL ROADWAY WORKER ACCIDENT
A veteran NYCT track worker was struck by a train and killed while setting up lanterns to warn trains to slow down in advance of a trackside work area on April 24, 2007. A local train had stalled due to brake problems and a train behind it was diverted to the express track. Central control personnel did not know the trackside workers had begun work, and the diverted train could not stop in time to avoid hitting the worker.
Probable Cause

A Board of Inquiry into the accident determined that the probable cause of the accident was the roadway worker's belief that southbound revenue service had ended.

Contributing Cause Factors
The Board of Inquiry found as a contributing factor that the job supervisor failed to properly follow flagging procedures. Further, not all roadway workers—supervisory or nonsupervisory—were supplied with radios.

NYCT'S APRIL 29, 2007 FATAL ROADWAY WORKER ACCIDENT
Another veteran NYCT worker, a painter, was killed instantly on April 29, 2007, when struck by a train that had just come around a sharp curve. The view of the train operator was obscured by the station platform, and no warning signals or devices had been set to warn the train operator of the work being performed. The train also struck and seriously injured a second roadway crewmember.

Probable Cause
The Board of Inquiry found that the probable cause of the accident was the supervisor's abandoning of his flagging responsibilities.

Contributing Cause Factors
NYCT's investigation found "clear deficiencies in flagging activities, including adjacent track flagging, caution lights and portable train trip positioning relative to the work area, and poor compliance with flagging requirements identified during the pre-job inspection." An NYCT employee survey also revealed a perception among employees that employees who only perform flagging jobs are much better flaggers and, as a result, flagging for contractors is stronger than flagging by NYCT employees. The employee survey also noted that near-hit incidents are frequent and most go unreported due to a fear of reprisal, a feeling that "nothing will get done," or a desire not to get a coworker in trouble.

WASHINGTON D.C.
The Washington Metropolitan Area Transportation Authority's (WMATA's) fatal roadway worker accidents:

- WMATA's fatality on August 9, 2009
- WMATA's fatalities on November 30, 2006
- WMATA's fatality on May 14, 2006

WMATA's AUGUST 9, 2009 FATAL ROADWAY WORKER ACCIDENT
A Washington Metropolitan Area Transit Authority (Metro) roadway worker was struck and killed by ballast regulator vehicle on August 9, 2009, while he was replacing cross ties on the Metro system's roadway.

Neither the probable cause nor the contributing causes have yet been determined in this accident, although it is apparent that the worker was working on the track did not do what was necessary to avoid being struck by the approaching ballast regulator.

WMATA's NOVEMBER 30, 2006 FATAL ROADWAY WORKER ACCIDENT

A northbound Metro Yellow Line subway train struck and killed two Metro employees performing a walking inspection of the track on November 30, 2006. The northbound train was traveling along track normally used for southbound trains.

Probable Cause

The NTSB determined that the probable cause of this accident was the failure of the walking track inspectors to maintain an effective lookout for trains and the failure of the train operator to slow or stop the train until she could be certain that the track workers were aware of the train's approach and had moved safely aside. Both track workers had previously called the Metro Control Center to receive permission to walk on the track. The Control Center made blanket radio announcements to train operators notifying them of the work and the approximate location of the track workers. The operator of the northbound train which struck the track workers stated that she did not recall having heard the radio announcements.