FTA Report No. 0212

FTA RESEARCH
FEDERAL TRANSIT ADMINISTRATION

FTA Standards Development Program: Rail Transit Roadway Worker Protection

PREPARED BY
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Dingqing Li
Matt Holcomb
Michael Brown

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

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Federal Transit Administration

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Courtesy of Mike Brown, TTCI

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Metric Conversion Table

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

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Abstract

This research reviewed existing standards and best practices and develops use cases, a risk assessment matrix, and high-level concepts of operations (CONOPS) for Rail Transit RWP. The project evaluated current industry practices and technologies in use for roadway worker protection and conducted a risk/hazard analysis of current practices using an industry-representative survey, available National Transportation Safety Board (NTSB) accident reports, and National Transit Database (NTD) incident data. This process was also used to develop RWP use case scenarios. RWP CONOPS were developed to reduce identified risks associated with the work performed by roadway workers, and a gap analysis was conducted of operational methods and current available and emerging technologies that can improve roadway worker safety.

This report was prepared for the Federal Transit Administration through the Center for Urban Transportation Research (CUTR) by Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), Pueblo, CO. It is based on investigations and tests conducted by TTCI with the direct participation of FTA and CUTR to criteria approved by them.

Executive Summary

The Transportation Technology Center, Inc. (TTCI), with support from the Center for Urban Transportation Research (CUTR) at the University of South Florida, was tasked by the Federal Transit Administration (FTA) to research and review existing standards and best practices and develop use cases, a risk assessment matrix, and high-level concepts of operations for transit rail roadway worker protection (RWP).

The literature review consisted of reviewing available literature on incident reporting and safety practices at both U.S. and non-U.S. transit agencies. An industry survey provided insights into procedural and operational differences among individual transit agencies. Responses indicated that most rail agencies are using modified versions of the Federal Railroad Administration (FRA) Roadway Worker Protection regulations (49 CFR Part 214 Subpart C) to address RWP practices. National Transportation Safety Board (NTSB) reports and National Transit Database (NTD) incident reporting data revealed that there are several potential hazards that should be addressed, including miscommunication, inattention, improper protection, and incapacitation.

Review of available emerging technologies determined that existing technologies are able to provide only a secondary level of protection for roadway workers. However, by overlaying these technologies with existing policies and procedures, relative risk to roadway workers can be reduced.

TTCI developed a comprehensive document describing most transit rail use cases. These use cases should be helpful for transit agencies to use as benchmarks to identify most significant hazards encountered by roadway workers and possibly improve RWP policies and procedures.

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

The research team also developed high level concepts of operations (CONOPS) of a roadway worker protection (RWP) safety system (secondary warning devices) that is intended to reduce the risk of transit rail roadway workers while engaged in activities within the roadway. The CONOPS can be used in conjunction with current practices to improve overall safety for roadway workers and includes a suite of risk-reducing concepts which, when used together or individually, may improve worker safety by enhancing situational awareness of roadway workers for specific use cases. Together with policy, rules, trainings, and guides, secondary worker protection devices as outlined in CONOPS can be effectively deployed to help reduce worker risk.

A gap analysis showed that technologies have limitations as secondary warning devices and also identified incapacitated workers and procedure non-compliance as areas that could be addressed by agency RWP programs.

Findings

- 70% of respondent transit rail agencies are using, to varying extents, the Federal Railroad Administration (FRA) Roadway Worker Protection (RWP) regulations contained in 49 CFR Part 214, Subpart C – Roadway Worker Protection. Most programs cover Individual Train Detection (ITD) (Lone Worker) protection methods.
- A literature review and NTD database review revealed several hazards that current rules and regulations do not fully address, including miscommunication, inattention, improper ITD assessment/application, and incapacitation.
- Incident reports documented multiple instances in which roadway workers were struck by a rail vehicle; a common causal factor was determined to be poor-quality job safety briefings at different operational and organizational levels.
- A hazard/risk assessment matrix incorporating the field of human factors and risk analyses based on various use cases and implementation of secondary RWP protection devices based on a high-level Concept of Operations (CONOPS) of an RWP safety system may help agencies to improve RWP.
- Available RWP technologies are designed to provide additional warning to workers and train crews, but they do not serve as primary protection. Overlaying these technologies may enhance RWP.
- Additional RWP technology advancements and future research are necessary for further equipment and combined operational improvements.

Section 1

Introduction

Transit rail Roadway Work Protection (RWP) is a critical component of a modern Rail Transit Agency (RTA). Each RTA is a highly complex system of equipment and human factors that interact on a daily basis under highly-variable conditions that can come together to pose significant risks to the safety of workers on the right-of-way; when these risks are not properly addressed, they can lead to damaged equipment, severe injury, and death.

Under this research project, the Transportation Technology Center, Inc. (TTCI), with support from the Center for Urban Transportation Research (CUTR) at the University of South Florida, was tasked by the Federal Transit Administration (FTA) to research and review existing standards and best practices and develop use cases, a risk assessment matrix, and high-level concepts of operations for transit rail RWP.

This project had the following objectives:

- Conduct a literature review to evaluate current industry practices and technologies in use for roadway worker protection.
- Conduct a risk/hazard analysis of current practices using an industry-representative survey and an analysis of available National Transportation Safety Board (NTSB) accident reports and incident data from the National Transit Database (NTD), including development of use case scenarios involving RWP.
- Develop high-level CONOPS for RWP that can be used to reduce identified risks associated with work performed by roadway workers.
- Conduct a gap analysis of operational methods, current available technologies, and emerging technologies that can improve roadway worker safety.
- Summarize findings in a technical report.

To foster collaboration for this research, an advisory group was established consisting of representatives of transit agencies of varying size and types and committee members of CUTR’s Transit Standards Working Group. The group served as a technical advisory committee to which draft documents and concepts were presented for input and feedback to ensure that experiences or insights held by transit agencies were included in the research and findings. The advisory group played a vital role in the development of transit rail RWP use cases, a hazard assessment matrix, and the concept of operations for an RWP safety system, as described in detail later in this report.

Section 2 Current Practices and Causes of Incidents

TTCI performed a literature review of current RWP practices and technologies in use in the transit rail segment of the industry. Generally, RWP programs vary in scope and thoroughness among agencies. A majority of the programs contain elements that mirror those of FRA's Roadway Worker Protection regulations (49 CFR Part 214 Subpart C); however, each set of RWP protection procedures and policies is unique to the individual transit agency. The American Public Transportation Association (APTA) has published several standards that provide guidance and recommended best practices as they relate to RWP. Review of several sources shows that RWP programs generally contain a combination of the following elements:

- Procedures and policies on job briefings
- Procedures and policies on establishing working limits and/or on-track protection
- Procedures and policies on certification and recertification training of roadway worker qualified employees/contractors.

A summary of additional elements of an RWP program from several sources including FRA, the California Public Utilities Commission (CPUC), and APTA is provided later. APTA has no regulatory enforcement authority and, as such, these standards serve as guidelines rather than regulations.[1]

NTSB accident reports reveal that in multiple instances in which roadway workers were struck by a rail vehicle, there were concerns about the quality of job briefing performed prior to the incidents.[2] These concerns generally involved one of the following:

- Job briefing incomplete – information missing or details related to how to properly protect oneself left out of briefing.[3]
- Job briefing not fully understood – details not fully understood by those participating in briefing, details and information forgotten, or no feedback

[1] APTA, Roadway Worker Protection Program Requirements, October 6, 2016, APTA-RT-OP-S-016-11; APTA, Work Zone Safety Practices, October 6, 2016, APTA-RT-OP-S-004-03.

[2] NTSB, 2008, Washington Metropolitan Area Transit Authority (WMATA) Train Strikes Wayside Workers Near Eisenhower Avenue Station, November 30, 2006, RAB-08-02; NTSB, 2008, WMATA Train Strikes Wayside Workers Near Dupont Circle Station, May 14, 2006, RAB-08-01; NTSB, 2019, Railroad Accident Brief: New York City Transit Train Strikes Two Flagmen, November 3, 2016, RAB-19-03; NTSB, 2015, Railroad Accident Brief: Bay Area Rapid Transit Train 963 Struck Roadway Workers, October 19, 2013, RAB-15-03.

[3] NTSB, 2008, WMATA Train Strikes Wayside Workers Near Eisenhower Avenue Station, November 30, 2006, RAB-08-02; NTSB, 2019, Railroad Accident Brief: New York City Transit Train Strikes Two Flagmen, November 3, 2016, RAB-19-03.

elicited by Roadway Worker in Charge (RWIC) to ensure that all aspects of briefing clear before commencing work.[4]

- Job briefing was not fully communicated – job briefings completed with one party (train crew and dispatcher or roadway workers and dispatcher) not communicated to other parties who needed information.[5]

At the time these incidents occurred, the roadway workers in question were responsible for providing their own trackside protection. In every case, no form of exclusive track occupancy (ETO) was established even though most transit agencies have provisions for some form of exclusive track protection available for use by roadway workers.[6] ETO is considered a state of protection in which no traffic can enter the working limits/area where roadway workers are present; it is the most secure form of track protection available to roadway workers.

A 2012 National Academies of Sciences review of wayside transit worker protection practices shows differing complexities among individual transit agency RWP.[7] One agency has a program that almost exactly copies what would be expected in a freight railroad operating environment that falls under FRA jurisdiction; another has a system comprising five levels of protection, of which four involve some form of flagging or watchman/lookout and one could be classified as ETO.

An issue prevalent at almost all transit agencies is relatively short headways, i.e., the time between revenue service trains. Short headways limit the use of ETO as a method of track protection during operations, as it can create schedule delays or overly-complex arrangements to "run-around" work areas. For work that is relatively small in scope, RTAs may determine that the associated ETO costs and impacts on train operations outweigh any perceived benefit, so roadway workers typically fall back on an alternative method of protection such as watchmen/lookouts, flagging, portable lights, advanced train warning detection, and enhanced communication procedures with Dispatch/Central and work crews.

The literature reviewed discussed establishing working limits on transit rights-of-way, and most references referred to conversations between roadway workers and a dispatcher or control operator responsible for rail traffic movements. The level of this type of involvement in the RWP process varied

[4] NTSB, 2008, WMATA Train Strikes Wayside Workers Near Eisenhower Avenue Station, November 30, 2006, RAB-08-02; NTSB, 2008, WMATA Train Strikes Wayside Workers Near Dupont Circle Station, May 14, 2006, RAB-08-01.

[5] NTSB, 2008, WMATA Train Strikes Wayside Workers Near Dupont Circle Station, May 14, 2006, RAB-08-01; NTSB, 2019, Railroad Accident Brief: New York City Transit Train Strikes Two Flagmen, November 3, 2016, RAB-19-03; NTSB, 2015, Railroad Accident Brief: Bay Area Rapid Transit Train 963 Struck Roadway Workers, October 19, 2013, RAB-15-03.

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

[7] *Ibid*.

from agency to agency, with the process becoming more complex if there is roadway work equipment, construction materials, non-revenue rolling stock, and hi-rail vehicles in the work environment. In at least one instance, the presence of trackside work groups and hi-rail equipment moving between work locations directly contributed to a fatal incident.[8] In another instance, procedures in place for roadway worker protections were followed by the dispatcher and the roadway workers specifically but still resulted in fatalities of members of the roadway work group due to being struck by a train.[9]

Incidents of regulations non-compliance have occurred at commuter rail agencies that fall under the safety jurisdiction of FRA. In cases reviewed, there were rules and procedures in place that were specifically designed to provide positive protection for roadway workers but were either not complied with or improperly complied with, which directly contributed to accidents and fatalities in some cases.[10]

Rail Accident Investigation Branch (RAIB)

TTCI also reviewed incident reporting from Europe. Although the rules and regulations in Europe may be different from those used in the U.S., and the rail network varies greatly, the principles of RWP can be considered universal. Within the last 5–10 years, Great Britain experienced numerous roadway worker fatalities, injuries, and near-miss incidents,[11] an issue so serious that RAIB, which is analogous to NTSB in the U.S., commissioned an in-depth study of incident reports to determine RWP safety issues with the goal of making recommendations to rail network operators to improve worker protection. RAIB reviewed incident reporting data for a two-year period; their analysis revealed the following:

- Operating irregularities related to application of track protection were significant in nature, occurred frequently, and showed no sign of reducing over time.
- A variety of safety issues, including miscommunication, violations, lapses, and incorrect understanding of protection limits, were putting roadway workers at risk 3-5 five times per week.[12]

[8] NTSB, 2012, WMATA Hi-Rail Maintenance Vehicle Strikes Two Wayside Workers Near the Rockville Station, January 26, 2010, RAR-12-04; NTSB, 2019, Railroad Accident Brief: Metropolitan Atlanta Rapid Transit Authority Train 401 Strikes On-Track Equipment, June 3, 2018, RAB-19-04.
[9] NTSB, 2015, Railroad Accident Brief: Bay Area Rapid Transit Train 963 Struck Roadway Workers, October 19, 2013, RAB-15-03.
[10] NTSB, 2014, Railroad Accident Brief: Metro-North Railroad Employee Fatality, May 28, 2013, RAB-14-10; NTSB, 2014, Railroad Accident Brief: Metro-North Railroad Employee Fatality, March 10, 2014, RAB-14-13.
[11] RAIB, 2015, Class Investigation into Irregularities with Protection Arrangements during Infrastructure Engineering Work, Department of Transport, August.
[12] *Ibid*.

RAIB broke down events with operational irregularities that could have led to significant incidents into the nine broad classification categories summarized in Table 2-1 and further into likely causes that could be attributed to each of the nine categories:

- Incorrect understanding of protection limits
- Incorrect instructions given
- Correct instructions not followed
- Lack of awareness
- Misunderstanding or communication errors
- Violations or lapses
- Poor understanding of rules
- Incorrect understanding of planning information (e.g., planned work limits)

Table 2-1 *Percentage of All Incidents by Classification Investigated by RAIB*[13]

Incident Category	Description	Percentage of All Incidents
Protection equipment incorrectly placed	Events involving errors with positioning of protection and other equipment such as detonators, possession limit boards, and work site marker boards.	33%
Work carried out without protection	Events involving various scenarios where work performed with no suitable safety precautions in place.	13%
Working outside protected work area	Events in which work performed outside area protected by track possession or track blockage.	12%
Trains incorrectly signaled into protected work area	Events involving trains improperly entering track block or possession that had yet to be released.	12%
Protected work area set up while line open to traffic	Events involving granting of blocks on sections of lines still occupied by trains or without confirming section was clear of traffic.	9%
Work incidents within protected area	Events involving unauthorized movements, collisions, derailments, improper switch operation, others.	9%
Electrical protection irregularities	Events relating to risk of staff receiving electric shock when working on/near conductor rails or overhead catenary electric line equipment.	5%
Safety issues when protected work area given up	Events involving release of possession or track blockage when track not clear or not safe to run traffic across.	4%
Road crossing irregularities within protected work area	Events related to passage of trains over road crossings through work areas when crossing protection down or inoperable.	3%

[13] *Ibid*.

Close Call Reports

A close call is defined as "an opportunity for improving safety practices in a situation with a potential for more serious consequences." An analysis of close calls is pertinent to RWP for many reasons, as very often they go unreported or are routinely under-reported. However, reporting and analyzing these events offer critical insight into safety issues and serve as an advance warning of inherent problems with unauthorized work practices, policies and procedures, and safety enforcement practices. TTCI researchers reviewed a close-call report by the Washington Metropolitan Area Transit Authority (WMATA), a U.S. heavy rail transit agency,[14] and found that over a five-year period, 111 close-call reports were received,[15] with the top three safety concerns being the following:

- Unsafe work practices
- RWP
- Defective equipment/infrastructure

All RWP close call reports were related to rules or procedures not being followed by the Operations Control Center, the RWIC, or supervisors. Recurrent themes across all reports were communication failures between parties, inadequate job briefings, and non-compliance with rules or policies. Additional analysis showed that many close calls occurred in mainline operating environments followed by shop, station, and yard environments. Figure 2-1 shows a breakdown of the 111 close calls reported by whether the employee making the report observed the close call or physically experienced the close call.

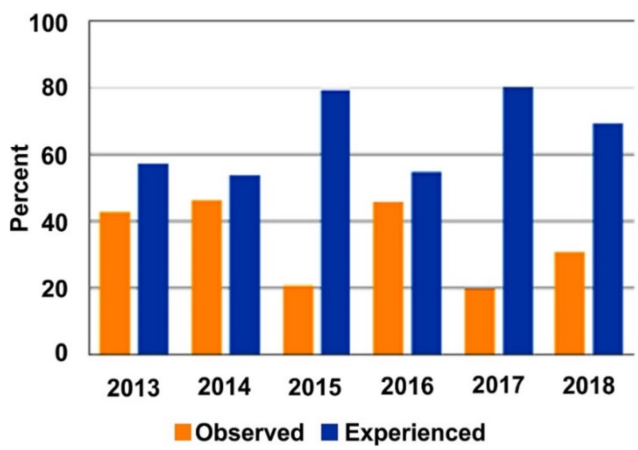


Figure 2-1 *WMATA close calls by observation or first-hand experience, 2013–2018*

[14] Bureau of Transportation Statistics, 2019, WMATA Close Call Program Report 2013–2018, https://doi.org/10.21949/1504250.
[15] *Ibid.*

For each reported close call, a root cause analysis was performed to identify contributing factors that led to the occurrence, broken down into contributing factors and root causes; a contributing factor was anything that aided in triggering a close call. Figure 2-2 shows the breakdown for the five-year period of review. The report also notes that a close call can have multiple contributing factors.

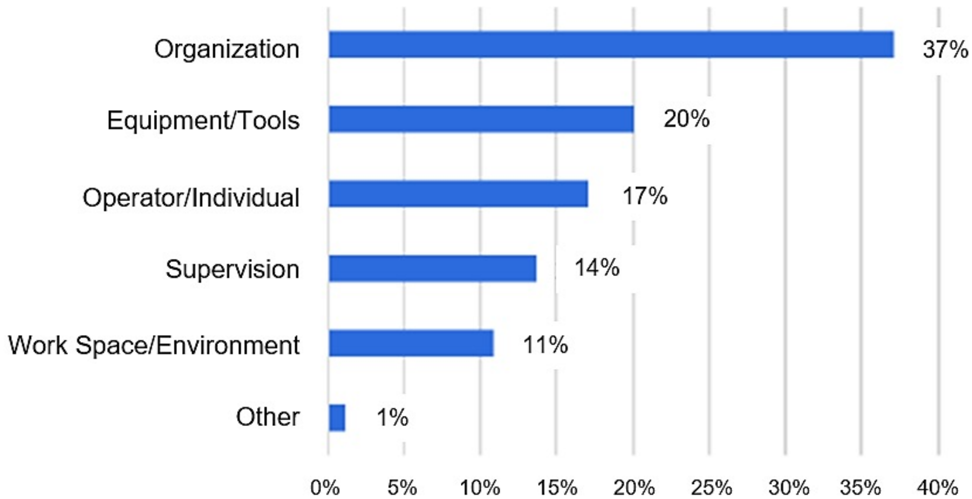


Figure 2-2 *Contributing factors in WMATA close calls, 2013–2018*

As shown in Figure 2-2, the leading contributing factor was organization, the organizational characteristics of the agency including management structure, reporting relationships, communication channels, rules and regulations, procedures and policies, and audits. WMATA also broke down the root causes for close calls in the five-year period analyzed, as shown in Figure 2-3.

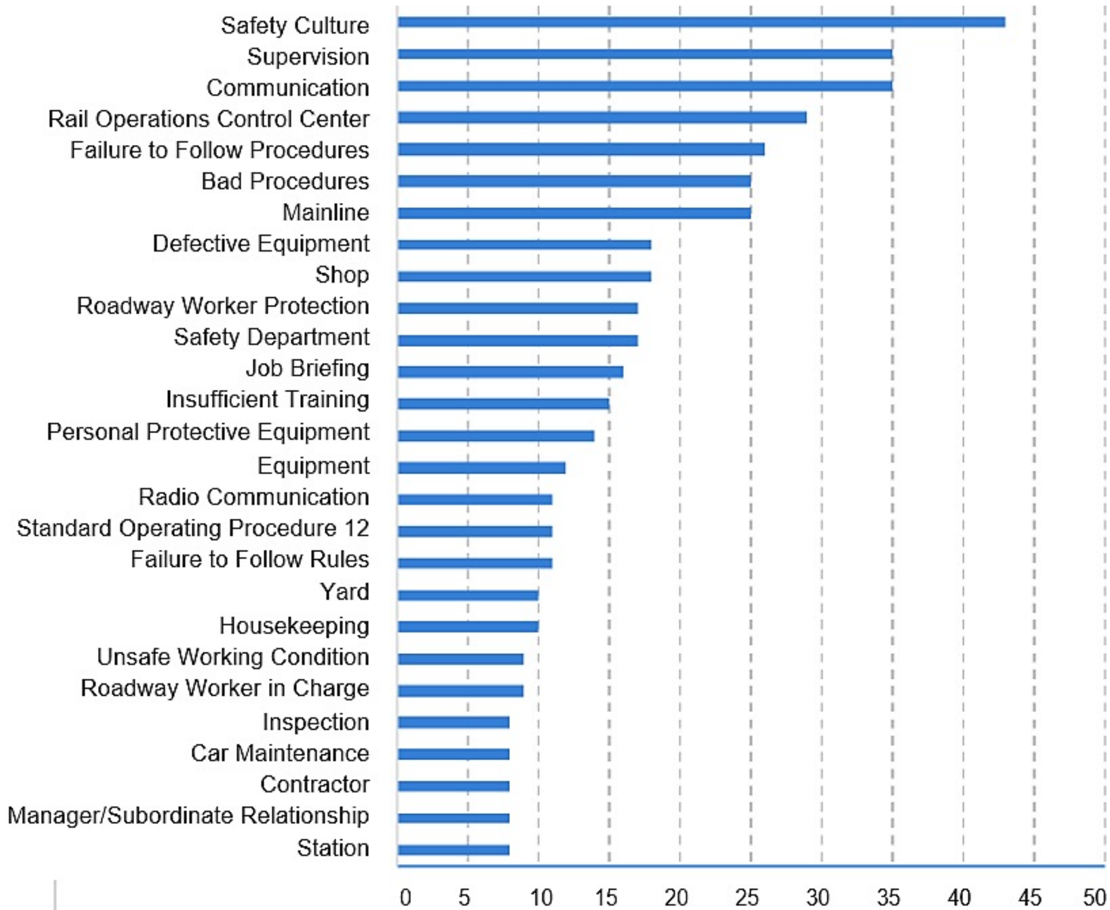


Figure 2-3 *Root causes of WMATA close call events, 2013–2018*

NTD Data

TTCI reviewed incident data available from the NTD for 2008–2017, which showed that approximately 11,196 were in the transit rail sector; further filtering narrowed the available dataset down to 21 incidents with a link to roadway workers or RWP. These incidents were reviewed and categorized using the general hazard groups as shown in Figure 2-4. In total, 17 incidents could be classified as inattention hazard/risk, 2 were miscommunication-related, and 2 were the result of incapacitation of the roadway worker. No incident could be classified as improper use of individual train detection. These 21 incidents resulted in 11 fatalities and 11 injuries ranging from minor to life-threatening.

NTD analysis of RWP incidents over the last 15 years shows an upward trend in fatal or injurious incidents. Reporting from safety agencies such as NTSB and RAIB revealed the need to reassess the practices and technologies in use for RWP and make improvements.

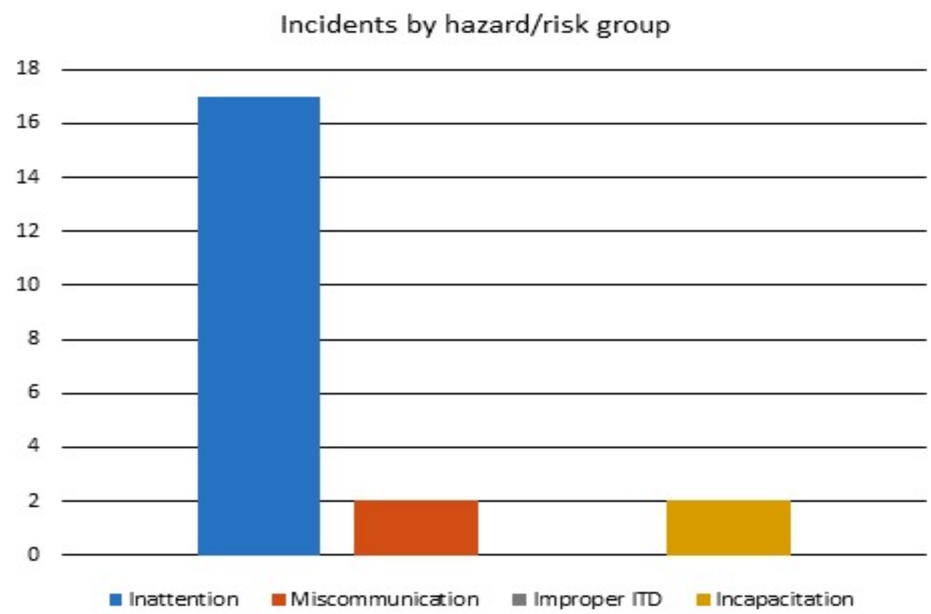


Figure 2-4 *NTD recorded incidents by hazard/risk group classification, 2008–2017*

Section 3

Elements of an Effective Transit RWP Program

This section summarizes elements of an effective transit RWP program based on best practices and regulations from APTA-RT-OP-16-11, Rev. 1, CPUC General Order 175-A regulations, and FRA regulations at 49 CFR Part 214. When implementing or improving an RWP program, these references and others should be reviewed in their entirety and adapted to an agency's operational environment.

An RWP program is clearly defined by policy, established by training, implemented by work crews, and continuously improved through an SMS (Safety Management System) approach. An agency should implement an RWP training program that matches the transit agency's size, complexity, and safety performance goal by considering common RWP elements that have proven to mitigate safety events and occurrences. Training programs should emphasize rules, procedures, and crew responsibilities, and required training should be periodically administered based on employee risk and agency safety goals. Agencies may consider integrating the RWP hazard identifications gathered by good faith challenges into their employee safety reporting programs.

Following are examples of three RWP programs.

APTA

Before anyone works on a track, the qualified employee in-charge (RWIC) conducts a briefing covering all anticipated safety, operational, and work topics; additional briefings may be required throughout the job due to changing circumstances. Individuals are responsible for knowing and following all safety rules, but rules specific to the work can be reiterated by the RWIC. Emergency and rushed operational conditions do not alleviate the requirement for on-track safety briefings. Lone workers must communicate with RWIC at the beginning of the work and receive the safety briefing, then advise the crew of their itinerary and on-track safety procedures. Refer to APTA-RT-OP-16-11 (latest revision) for minimum safety briefing topics.

APTA's standard describes suggested on-track safety rules and procedures and identifies a qualified person in charge or RWIC who is responsible for work crew's on-track safety. Safety briefing points include working limits, work limits using ETO, on-track protection on non-controlled track, work limits using foul time procedures, on-track protections beyond working limits, and on-track lone worker protections.

APTA also describes suggested actions to be taken by the RTA, which establishes maintenance and inspection protective measures required outside the working limits. The RTA determines additional work crew protections during other-than-normal operations (i.e., single tracking, stuck-switches, etc.) and for trains approaching a work crew during non-normal operations. RTAs are responsible for identifying hazardous RWP conditions beyond that described above and incorporating procedures to mitigate those hazards. For specific requirements concerning on-track equipment safety, refer to APTA RT-S-OP-021-15, Standard for On-Track Equipment Safety Requirements.

CPUC

The California Public Utilities Commission (CPUC) General Order 175-A includes all APTA RWP requirements identified above and includes a comprehensive definition section. CPUC defines the work crew leader as the Employee in Charge (EIC). Maximum authorized vehicle speed is determined by the 15-second rule to determine vehicle speed (time for work crew to vacate a work zone).

CPUC defines some minor tasks that can be accomplished by a single individual using Lone Worker Protection procedures that include retrieving or removing an item from the work zone, aligning manual or electric switches, flag placement or removal, taking photos (with restrictions), or visual inspection at one fixed location due to immediate need.

General Order 175-A imposes the following additional RTA responsibilities beyond APTA recommendations. RTAs must:

- Follow training requirements specifically laid out in Section 9 of the General Order
- Use the 15-second rule
- Establish a RWP compliance and testing program
- Have written flag protection rules (Section 3.5)
- Determine required safety equipment
- Include a personnel escort requirement or prohibition of access for those not RWP trained or those trained at an insufficient level of protection for the activity

The General Order breaks down individual responsibilities, knowledge, and on-track safety briefing and conditions communications requirements.

Job briefing requirements are explicitly explained in Section 5 and are more detailed than the APTA standard. Topics include general work plans, expected hazards, personal protective equipment (PPE), identification and location of the EIC, proper flags and flag placement, places of safety, 15-second rule requirements and considerations, means of communication, employee acknowledgement of rules, watchmen duties, and requirements to re-brief upon relocation.

Section 6 of the General Order describes controls and limitations for on-track work other than in the yard or on tracks at the end of lines (tail-tracks). Topics covered include moving from one location to another, performing minor tasks, visual inspections, maintenance, and repairs, and using machines, equipment, and hand-tools. CPUC also describes controls and limitations for yard and end-of-line track work. Refer to General Order sections 6.3 and 7 for full details.

The General Order describes protections for emergency response personnel which include requirements for an emergency response plan, provisions of the emergency response plan, RTA first-responder training, and RTA employee emergency response training. Section 9 details RWP training requirements that include implementation of an RWP training program, employee applicability, program updates based on safety data, minimum training requirements, and trainer competencies. The General Order also describes safety reporting and records requirements.

FRA

FRA's RWP regulation at 49 CFR Part 214 Subpart C prescribes minimum safety standards for roadway workers and safety standards related to the movement of roadway maintenance machines where such movements affect the safety of roadway workers. The regulation contains similar elements as the APTA standard and the CPUC General Order but is more comprehensive. As this FRA regulation was designed for a traditional railroad environment, agencies may elect to include more transit-specific procedures that fit their operational environment.

This summary of selected FRA regulatory provisions does not include all sections of the regulations; thus, the applicable regulations must be reviewed in their entirety. The FRA RWP regulation requires that all regulated railroads implement an FRA-approved RWP program, which must include an on-track safety manual that is readily available to all affected workers. Section 214.315 of the regulation provides minimum safety actions that must be followed prior to allowing an employee to foul a track, and Section 214.318 requires that locomotive, car shop, and yard track areas be protected by Blue Light procedures as described elsewhere in FRA's regulations.

Section 214.317 prescribes on-track safety procedures including track crossing procedures, on-track protections, places of safety (including tunnels and tunnel niches), tool and equipment control, and maintenance machinery (snow and weed control) considerations. Train speed and crew separation are defined by one-half the range of vision but not exceeding 25 mph. The regulation describes communication requirements between on-track equipment and other on-track movements. Remote-control work equipment operations are prohibited unless approved by the RWIC. FRA prescribes a 15-second rule for lone workers and allows RWICs and lone workers to determine a place of safety other than a tunnel portal or clearing bay.

Section 214.319 prescribes working limits established to include procedures, crew coordination, and controlled (signalized) track considerations (Class 1 and 2 railroads).

Section 214.320 prescribes maintenance machine movements over signalized non-controlled track with a requirement to not exceed 25 mph or a speed that allows a train to stop within one-half range of vision, whichever is less.

Section 214.321 prescribes the working limits that must be established on controlled track through the use of ETO procedures. ETO work limits can be established using flagmen, a fixed stop signal, a station (listed on timetable), stop signals indicating prohibition of train movement (beyond the station), clearly identifiable milepost signs, and a clearly identifiable physical location in accordance with railroad operating rules. As set forth in 214.321, the RWIC has ultimate control of maintenance machine movements within the work limits, and work limits within the ETO can resume behind designated trains moving through those work limits. Work limits will be confirmed by the RWIC or lone worker only when trains are visually identified or are in direct communication with RWIC or the RWIC is in direct communication with the dispatcher/control operator. Reverse train movement into fouled work limits is prohibited. The RWIC or lone worker must record train movements (Train ID) once the train has departed the work area, and the time must also be recorded if communicated to the train or dispatcher/control operator. Workers must receive confirmation to foul track from the RWIC once the RWIC has fulfilled all responsibilities under the regulation. Another qualified RWIC-level worker (with a copy of the authority) may execute communications responsibilities and accompany other employees.

Section 214.322 describes ETO electronic display precautions and procedures.

Under Section 214.323, foul time procedures must comply with the following: 1) foul time given by dispatcher/control operator can only occur after that employee has withheld authority of all trains or other on-track equipment to move into or within the work limits during foul time, 2) each roadway worker must repeat track number (or identifier) to the issuing employee for verification before foul time, 3) dispatch/central cannot permit movement of trains or on-track equipment into working limits protected by foul time until RWIC reports work limits are clear, and 4) the RWIC cannot permit movement of trains or on-track equipment into or within work limits protected by foul time.

Section 214.325 describes train coordination and movement through the work limits to be controlled by the RWIC.

Section 214.327 prescribes working limits on non-controlled or inaccessible track sections.

Section 214.329 prescribes TAW procedures provided by watchmen/lookouts, which are especially important because work crews rely upon watchmen/lookouts to stop trains from entering fouled work limits and to warn crews of impending hazards.

Sections 214.335 and 214.336 provide on-track safety procedures in general and for certain roadway work groups and adjacent tracks. Numerous incidents have been investigated by NTSB in which employees lost situational awareness and cleared to the wrong place of safety. Section 214.336 also provides information about work limits and considerations about maintenance alongside maintenance machines or coupled equipment on and around adjacent track. The regulation accounts for background noise, lights, sight obstructions, or other physical limitations posed by using maintenance machinery.

Section 214.337 prescribes on-track safety procedures for lone workers. Of note, individual train detection protection can be used only 1) by a fully-trained and qualified employee, 2) for routine inspection and minor correction work, 3) on tracks outside the limits of manual interlocking, at a controlled point (except those consisting of signals only), or remotely controlled hump yard, 4) by visual train detection and movement to POS not less than 15 seconds before train arrives, 5) where no power tools or maintenance machines are used within hearing distance of the lone worker, and 6) where the ability of the lone worker to hear and see approaching trains and other on-track equipment is not impaired by background noise, lights, precipitation, fog, passing trains, or any other physical conditions. Lone worker identification of approaching trains and the ability to escape to a place of safety must take into consideration environmental conditions (e.g., fog, precipitation, passing trains, or other physical conditions). The POS cannot be another track not protected by established work limits. A lone worker using individual train detection must first complete a written Statement of On-track Safety, which includes the limits of track to be inspected, maximum authorized train speeds, and the sight distance that provides the required warning of approaching trains. The lone worker using individual train detection is required to produce the statement to an FRA representative upon request. Individual train detection must not be used to provide on-track safety for a lone worker using roadway maintenance machine or equipment/material that cannot be readily removed by hand.

Section 214.339 prescribes that railroads have written audible train warning procedures for initial and subsequent train warnings and alternative train warnings to lessen employees harm (i.e., tunnels and terminals). Audible warnings do not substitute for proper on-track safety procedures.

Section 214.341 prescribes roadway maintenance machine considerations and procedures including but not limited to machine operating qualifications, spacing between machines, and machine safety briefing requirements.

Sections 214.343 through 214.357 prescribe training and qualification based on specific roadway worker duties. FRA requires initial training followed by annual refresher training.

In addition to the above Subpart C requirements, 49 CFR Part 214 contains Subpart B, Bridge Worker Safety Standards, which covers fall protection standards and practices, working over or adjacent to water or scaffolding. The FRA regulations also contain Subpart D, On-track Roadway Maintenance Machines and Hi-rail Vehicles, which includes machine safety equipment, safety markings, safety design features, audible devices, retrofit requirements, rider safety requirements, flagging equipment, towing, and inspection and repair.

Section 4

Existing, New, and Emerging Technologies

Current technology used to protect transit rail roadway workers varies but is generally secondary protection. Procedures and systems for protecting transit rail roadway workers range from using a flagman to alert train crews to the presence of work groups on the right-of-way to using audible/visual warning devices and portable trip stops. Some agencies have performed in-house development of warning systems for their roadway workers, and others have used third-party applications from industry vendors. On a basic level, most agencies still use a verbal authority method to authorize and communicate right-of-way access protection—for example, the roadway worker calls a dispatcher or control center and requests permission to occupy a segment of track, the control center assures foul-time can be achieved, and then the worker is verbally given this permission via radio. This procedure is similar to the mandatory directives under FRA regulations. Many agencies document this process electronically by Dispatch and in written documentation by the roadway worker.

Existing advanced train warning technology should be used only as a secondary means of protection. These systems are designed to provide additional warning to the work crew, train operator, dispatcher/control operator or a combination of all but do not serve as primary protection because safety devices cannot prevent entry of rail traffic or on track equipment into the work limits/work area. Further, no secondary device has demonstrated capability to replace current practices used as primary protection.

New and emerging RWP technologies include systems of advance warning devices developed by various vendors that provide advance warning of approaching trains to roadway workers; some provide warning of roadway workers to train operators. These systems operate using radio, GPS, or magnetic- based alert devices that when approached by a train trigger an alert to roadway workers and possibly the train operator. However, all systems currently being marketed are forms of secondary protection and should not be solely relied upon for RWP. Nothing can prevent a worker from being struck by a train if there is no response to the warning device/system by the work crew or train operator. In most instances, a secondary warning device by design is intended to provide an additional layer of protection and is activated when an RWP procedure violation or some form of miscommunication has occurred.

FTA Demonstration Projects

In recent years, FTA has provided support and funding for several transit agencies to begin demonstration and evaluations of roadway worker advance warning device systems. These evaluations are all currently underway; none have been completed. Table 4-1 provides a brief synopsis and status of each project.

Table 4-1 *FTA-funded RWP Technology Demonstration Project Status*

Agency	RWP Focus Area	Project Status
MARTA	• Secondary warning system to track workers • Provides real-time presence/location of workers to control room operator • Provides minimum 15-second advance warning to train operators of track worker presence	Bombardier training to maintenance of way (MOW) workers in November 2019; demo underway with six-month data collection/evaluation
MTA (Maryland)	• Secondary worker protection system that provides advance warning to roadway workers of approaching train within MTA established minimum 25-sec safe clearing time before train arrival • Alerts train operators when approaching work zones	Testing phase began in February 2019, installation of train detection units in August 2019; system fully functional, web portal established to collect/maintain performance data during nine-month data collection phase
NY MTA	• Evaluates alternative methods of secondary RWP modules to identify optimal configuration • Provides 15-sec advance warning to workers of oncoming trains	Initial system testing completed in July 2018; final proof of concept demonstration report issued in January 2019
Sacramento RT	• Secondary warning to worker and signal protection with final warning to all right-of-way personnel, train operators, and rail vehicles when any authorized limits lifted • Minimum 15-sec warning to track workers	Final product installation completed in Fall 2019, software updates completed in December 2019; system fully functional; project included nine-month data collection
WMATA	• Secondary warning system to worker and signal protection with real-time information to dispatcher and minimum 15-sec warning to all right-of-way personnel and train operators	Installation on WMATA Red Line began March 2019; all system hardware/infrastructure installation, including 514 wayside devices, completed in September 2019; project included nine-month data collection phase

RWP in Europe

The British rail industry is further along than the U.S. in implementation of secondary RWP technology, as some areas have fully-functional secondary warning systems that can be triggered by either train passage or a roadway worker serving as a watchman/lookout. However, even with these types of secondary advance warning systems in place, near-miss incidents have occurred. One incident involved a work group of nine roadway workers who had to leap clear of the tracks to avoid being struck by a revenue service train traveling at maximum authorized speed for the track section. The section was equipped with a secondary warning device system due to the speed of traffic and sight distance limitations; the system would have given at least 50 seconds of warning via an audible siren tone. The RAIB investigation revealed that the work group EIC made an decision to ignore the audible alerts from the warning system so extra seconds could be spent working on the track. Based on head-end camera footage, the workers who jumped clear of the tracks did so just one second before the train arrived at their location.[16] This sequence is shown in Figures 4-1and 4-2. An incident such as this highlights that technology is not a replacement for proper rules and procedures with which all roadway workers must comply when they enter railroad rights-of-way.

Figure 4-1 *Head-end camera footage approximately 2 seconds before incident*[17]

Figure 4-2 *Head-end camera footage showing work group still clearing 1 second before incident*[18]

There are other incident reports in which a secondary warning system such as the one described above was not present but could have made a major difference in the outcome of the incident. For example, a two-man work team

[16] RAIB, 2018, Near Miss with a Group of Track Workers at Egmanton Level Crossings, Nottinghamshire, Department of Transport, August.
[17] *Ibid.*
[18] RAIB, 2018, Near Miss with a Group of Track Workers at Egmanton Level Crossings, Nottinghamshire, Department of Transport, August.

was dispatched to investigate a track circuit issue where they planned to use watchman/lookout protection; however, the location at which they were to perform the work—an interlocking location shown in Figure 4-3—did not have proper sight distance under certain conditions. Specifically, when an outbound train was present on the opposite track of the double main track, sight distance for any traffic inbound on the near track (which the roadway workers would be fouling) was impaired. The work group failed to recognize this risk and assumed they had proper sight distance. During their inspection, they were passed by an outbound train while an inbound train was simultaneously approaching them. Due to impaired sight distance, the inbound train did not see the workers until six seconds before reaching their location, at which time the horn was blown and emergency brakes were applied. The roadway workers, upon hearing the horn, moved to clear the track just two seconds before the train reached their location. In this situation, the presence of a secondary warning device, specifically one that alerts roadway workers of the presence of an approaching train independent of a lookout's warning, would have provided ample warning time for the work group to safely clear the work zone.

Figure 4-3 *Outbound train on far track obscures vision of inbound train near track at work location*[19]

[19] RAIB, 2018, Near Miss with Track Workers at Pelaw North, Department of Transport, August.

Section 5 Industry Survey

As part of a parallel effort to understand current industry practices, TTCI, in partnership with APTA, solicited responses to an industrywide survey on RWP practices. APTA distributed and collected answers for the survey, a copy of which included as Appendix A. The survey covered many different aspects of RWP, including the following:

- What the agency's operating rules are based on:
  - FRA regulations
  - Northeast Operating Rules Advisory Committee (NORAC) rules
  - General Code of Operating Rules (GCOR)
  - State regulations
- Use of protection methods such as watchman/lookout and lone worker
- RWIC protecting multiple work groups
- Use of technologies beyond those recommended by NTSB
- Time to be in the clear prior to arrival of on-track equipment or trains following a warning

Survey responses were received from 15 agencies of varying size across the U.S., as shown in Figure 5 1. In many cases, smaller agencies do not have networks as large or complex as their larger counterparts in the industry. Funding levels and sources of funding also vary based on the size of the network, with larger agencies commonly having much more robust operating budgets. This could be a factor related to technology implementation, as cost can be a major decision driver.

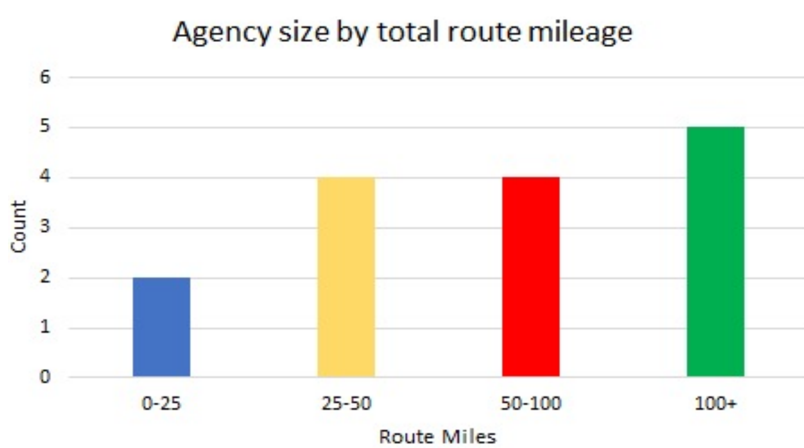
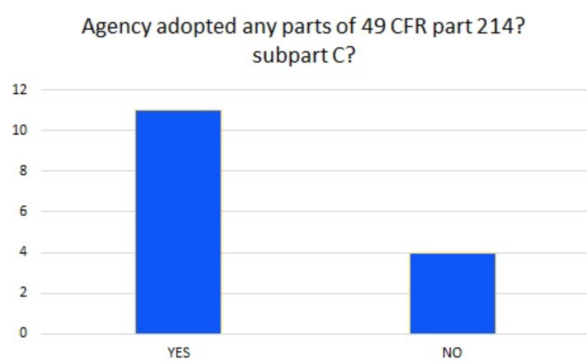


Figure 5-1 *Size of responding agencies by total route mileage*

Two questions focused on agency operating rules and their basis. A major difference between the transit rail industry and the North American freight rail industry is that transit rail systems are closed systems and do not require interoperability with other transit rail systems, whereas the North American freight rail industry operates on a system that requires interoperability. Each U.S. rail transit system responsible for crafting its own operating rules, consistent with State regulations; whereas the North American freight railroads all share similar rulesets that comply with FRA regulations, transit agencies do not have this requirement. FRA regulations serve as a unified base set of rules that many freight railroads then expand and modify (often to be more restrictive) to fit their own operating environments.

There is a variety of transit rail operating environments; although the lack of Federal rules and regulations allows for a large variance of protection rules from transit agency to agency, survey results indicated the opposite is occurring. Most agencies have adopted CFR 49 Part 214 (which addresses RWP) in whole or in part and have used other commonly-encountered operating rule conventions such as NORAC or GCOR as the basis for their rules. Figure 5-2 shows the response rates to two questions regarding each agency's operating rules. The responses appear to indicate that all agencies generally understand that FRA rules and regulations are a fundamentally sound system of protection, which can be useful as a starting point for their own systems of rules. Of the agencies that responded "no," four responded "no" to both questions, indicating that they have internal operating rules.



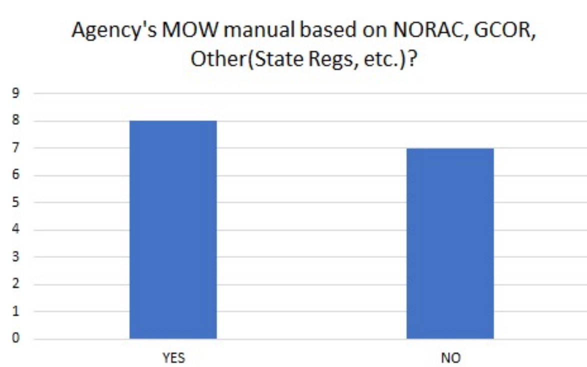


Figure 5-2 *Agency responses on basis for rules and practices*

Survey questions were also directed at gathering information on the use of two commonly-encountered protection methods for roadway workers in any environment—ITD (lone worker) and TAW (watchman/lookout) protection. Responses to these two questions, as shown in Figure 5-3, indicate that many agencies allow both methods of protection for workers wayside. Among agencies that responded “no,” two indicated that they do not allow the use of either form of protection on their respective systems.

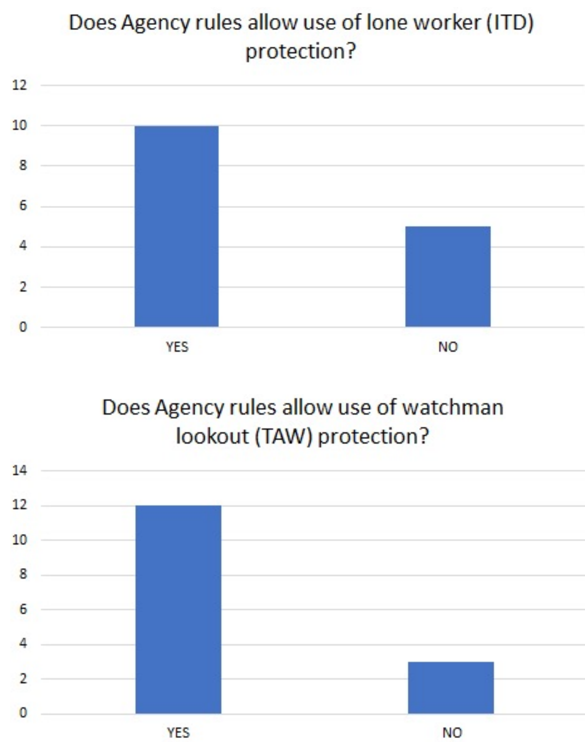


Figure 5-3 *Responses on use of ITD and TAW*

Another survey question was directed at determining if any transit agencies were using new or emerging technologies for RWP beyond those previously recommended by NTSB; Figure 5-4 shows that most agencies are not.

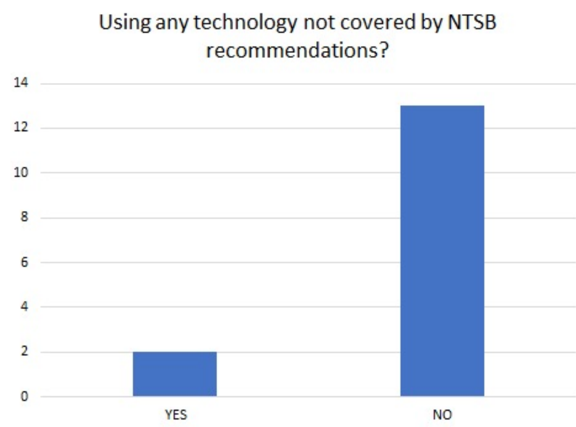


Figure 5-4 *Responses on use of new technologies*

Section 6

Potential Roadway Worker Safety Hazards

This section provides examples of potential risks while working under hazardous conditions. Based on the literature review and available incident reports, the following four hazards are currently not addressed by rules and procedures in place throughout the industry. Even with textbook application of operating practices, these hazards can still pose risks to roadway workers at any time on the right-of-way.

Miscommunication

Miscommunication is any error in relaying a message that causes the meaning of the message to be misunderstood. Roadway worker miscommunication can result in a failure to clear a hazardous situation, such as when roadway workers are working under the rules of Joint Occupancy. In this example, the EIC of the primary workgroup gives the order to that work group to clear the track for the movement of MOW equipment by the secondary work group. The EIC of the primary work group receives what they believe to be "clear of track" radio messages from all members of the work group. However, one of the radio transmissions was not clear—what the EIC heard as "clear of track" was actually "not clear of track for another 5 minutes." As a result, the EIC of the primary workgroup gives the EIC of the secondary workgroup permission to move on-track equipment through the area of track where members of the primary workgroup are still working. This miscommunication, potentially caused by a faulty radio transmission, introduces the potential risk of accidents, or even fatality, to the members of the primary workgroup still working on the track.

Inattention

Inattention is the failure of a roadway worker to give full attention to a situation resulting in a loss of situational awareness. Roadway worker inattention can lead to a roadway worker not being able to clear a hazardous situation in time. An example of this is inattention occurring while working under the rules of watchman/lookout. A watchman/lookout is responsible for alerting on-track workers of approaching trains and other potential hazards such as on-track equipment. This alert should allow for on-track workers to clear the track no less than 15 seconds (or an appropriate longer interval based on train speeds) prior to train arrival at the worker location. In this example, the watchman is distracted by another railroad employee that stopped to talk, which introduces a moment of inattention by the watchman, leading to the watchman not notice a train approaching until it is too late to provide the proper amount of advance warning. This situation introduces a potentially severe hazard to the on-track worker and his equipment.

Incorrect Individual Train Detection (ITD) Assessment

An incorrect ITD assessment is the failure of the roadway worker to correctly determine timetable train speed, available sight distance, or the amount of time required to clear the track. An ITD requires reassessment while performing work if any of these three factors change. If a lone worker wants to access track, it is their responsibility to perform an ITD assessment prior to fouling the track. An example of an incorrect ITD assessment may be due to a change in weather conditions—a lone worker arrives at the place on the track where they need to take a photograph of a switch. While performing the ITD work prior to fouling track, it begins to lightly rain, which the roadway worker does not take into account. By the time the ITD assessment is completed, it begins to rain heavily. The lone worker fouls the track to take a photograph but does not notice a train approaching due to noise and poor visibility from the rain; the train braking distance is increased on the wet rail. This situation increases the hazard of severe injury or death due to the ITD being conducted incorrectly.

Workman Incapacitated

An incapacitated workman is any workman who is unable to clear the foul limits of the track or perform their protection duties for other workers due to a physical impairment. For example, if a roadway work crew is working under ETO and authority is nearing the end time granted by the dispatcher, the EIC radios each work crew member to notify them to clear the track. Each workman then radios the EIC to confirm they have cleared the foul of the track. An incapacitated workman would increase the risk of not being able to clear the foul of the track.

Section 7

Roadway Worker Hazard/ Risk Assessment Matrix

TTCI researchers used information gathered in the literature review and industry survey to develop a prototypical risk assessment matrix designed to illustrate the inherent risks involved with various forms of RWP in a transit rail environment. The effort mimics closely what NASA and other agencies have done in their evaluation and management of organizational risks.

To a large degree, transit agencies should undertake similar efforts to assess risks/hazards within their organizations, essentially developing a risk assessment matrix suited to their style of operations and specific operating environment and rules/regulations. The TTCI research team sought to broaden this effort and create a generalized application of a hazard assessment matrix that could be used by any entity or agency in the transit rail industry. This risk assessment matrix may also be a critical tool in assessing hazards and risks as part of a Continuous Risk Management (CRM) structure. It is also useful in the development of CONOPS for an RWP safety system (secondary protection devices) that overlays new and emerging technological solutions to enhance roadway worker safety. CONOPS are discussed later in the report but are highlighted here to illustrate that the CONOPS solution is intended to further minimize risks as they have been identified in the risk assessment matrix.

Based on understanding of the factors that can impact any given action, TTCI established the following criteria for hazards and risks:

- Size of work group performing task
- Type of track protection selected for task
- Current traffic headways
- Perceived risk conditions of task to be performed

The last bullet above merits further discussion, as the first step of any roadway work group activity is a job briefing. The job briefing process is essentially a job-hazard analysis (JHA) performed in real-time immediately prior to an activity. JHAs are used to determine hazards that may be present based on evaluation of current and anticipated conditions. The job briefing's purpose is to attempt to capture all possible hazards that may be encountered. Once a comprehensive list of potential hazards has been compiled, evaluating the potential risk(s) and consequences associated with those hazards is the next step in the process.

MOW work is a regimented set of commonly-repeated actions and processes. Work activities such as replacing a rail occur frequently and involve almost identical sequences of work each time the activity occurs. Likewise, the surrounding operational environment typically has some conditions that are almost always the same. Things such as traffic headways, sight distances, and maximum authorized speeds in a specific section of track are typically known and unlikely to change. Therefore, TTCI developed several distinct risk classes based on the following common, ever-present, and unchanging hazards:

- Maximum authorized track speed
- Sight distance
- Clearances
- Number of tracks
- Presence of switches
- Presence of on-track equipment
- Type of work to be performed

Table 7-1 highlights the differences between low hazard and severe hazard categorizations.

Table 7-1 *Severity of Perceived Hazards*

Hazard Category	Low Hazard	Severe Hazard
Traffic speed	10 mph	Maximum authorized, i.e., > 50 mph
Sight distance	Unimpeded	Restricted, < 0.1 mi
Clearances	Readily-available	Not available or too far away
Number of tracks present	Single	Multiple bi-directional
Presence of switches	Not present	Present in varying quantities
Presence of on-track equipment	Single hi-rail vehicle	Multiple of varying types
Type of work	Visual/minor, tightening bolt(s)	Major, disruptive, disturbs track

By assuming hazards such as those shown in Table 7-1, TTCI developed a generalized hazard/risk assessment matrix that calculates and illustrates the potential risk of certain situations. However, there is one immediate downside to this approach—a roadway worker could be in a situation where some hazards are severe (for example, extremely limited sight distance) but others, such as traffic speed of 10 mph, are low. As this type of scenario does not perfectly fit into one of the three categories, the research team added the ability to select different conditions for each hazard category shown in Table 7-2, which highlights the differences between low hazards and severe hazards. This enables a degree of customization that can tailor hazard categories to more real-world conditions. Also added was functionality, which allows selection of different human performance shaping factors (PFS; see Appendix B). An example of this assessment matrix is shown in Table 7-2.

Table 7-2 *Example Hazard Risk Assessment Matrix for a Lone Worker based on Risk Level*

HEADWAY FREQUENCY	INFREQUENT	MODERATE	FREQUENT	
	HAZARD LEVEL	HAZARD LEVEL	HAZARD LEVEL	2 workers
PROTECTION	SEVERE	SEVERE	SEVERE	
Watchman/Lookout				
ETO				
Track OOS				

Color Legend	
	Acceptable, risks minimized to greatest extent possible
	Acceptable, not all risks minimized fully- use Extra Caution
	Undesirable, serious risks still unminimized, consider more restrictive protection method
	Unacceptable, MAJOR risks still present, DO NOT Proceed until more restrictive track protection is applied

This example illustrates that when more severe levels of hazards are present, some protection methods are inherently unacceptable. However, there are also some combinations of less severe hazard and traffic frequency that can decrease risk but not fully eliminate it. Tables 7-3 and 7-4 show examples of the selection tables for hazard categories and human PSFs.

Table 7-3 *Example Hazard Modifiers Used in Assessment Matrix*

Hazard Modifiers	
Speed	10
Sight distance	Unimpeded
Clearances	Readily available
Number of tracks	More than two
Switches	Yes, single
On-track equipment	Single hi-rail
Type of work	Minor, nondisruptive

Table 7-4 *Example Human PSFs Used in Assessment Matrix*

Human Performance PSFs	
Available time	Just enough
Stress state	Nominal
Complexity	Moderate
Experience/training	Nominal
Job aids	Nominal
Fitness for duty	Degraded fitness
Work processes	Nominal

The risk level for the combination of hazard level, protection type, and traffic frequency are approximated using the following calculation:

$$\textit{Total Risk} = \textit{Hazard Modifier} \times \textit{Protection Modifier} \times \textit{Group Size Modifier} \times \textit{Headway Modifer} \times \textit{Human Performance Modifier}$$

Qualitative values for each of these modifiers are proposed by TTCI to calculate and approximate the risk for any potential scenario. An example using this hazard/risk assessment matrix is further illustrated in the following section.

Section 8

RWP Use Case Development

To fully use the hazard assessment matrix to assess the risks of an RWP scenario, it is important to understand the different possible scenarios roadway workers might face. In coordination with the project advisory group, TTCI developed a set of general transit rail use cases for RWP that define scenarios in which processes are executed without error and system failures that have not occurred. Use cases are also the foundation for developing any concept of operations for a safety system, and when used in conjunction with tools such as the hazard assessment matrix, enable transit agencies to better understand the risks that may be present in combinations of different roadway work environments.

Most possible use case scenarios have been included to better minimize risks for roadway workers. If any use case was omitted, any risks associated with it would remain unaddressed. This effort began by considering, as a framework, the regulations established by FRA that address protection methods for roadway workers in the North American freight rail industry. Many North American operating rules such as GCOR or NORAC are based, in part, on FRA regulations. As shown by the results of the industry survey, most transit agencies are using protection procedures and policies that either draw directly from FRA regulations or mimic them very closely. With that in mind, TTCI and the advisory group developed a set of use cases as shown in Table 8-1. The full use case document describing all identified sub-cases for each use case set is included as Appendix C. As shown in Table 8-1, the use cases describe current operating practices and scenarios associated with establishing and maintaining RWP. Each use case set has many sub-cases within it that address different track configurations, another critical element in the process of assessing risk based on the hazards present in the current working environment (see Appendix C for details).

Table 8-1 *Use Case Sets for RWP (UC-RWP)*

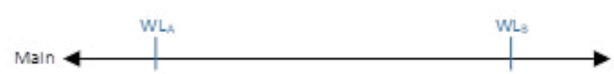
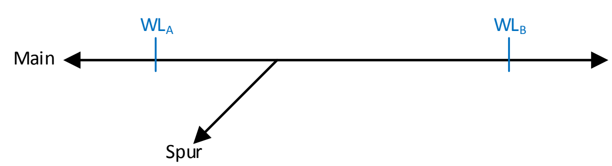
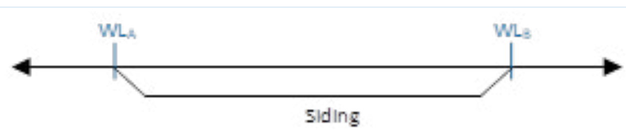
Use Case (UC) Set	Set Title	Description
UC-RWP-100	Lone Worker	On-track protection for Lone Worker who does not have formal exclusive track authority from Dispatcher
UC-RWP-200	Watchman/Lookout	On-track protection for group of roadway workers who do not have formal exclusive track authority from Dispatcher
UC-RWP-300	Acquisition of Exclusive Authority to Access Track	Roadway worker or roadway worker gang exclusive or joint authority to access track from Dispatcher
UC-RWP-400	Train Coordination	Roadway worker on-track protection when exclusive track authority ceded by train operator to EIC

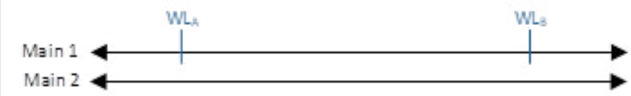
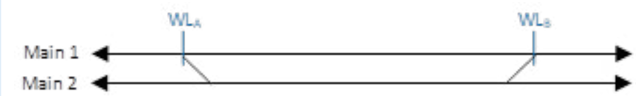
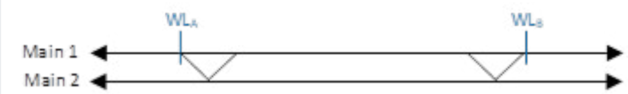
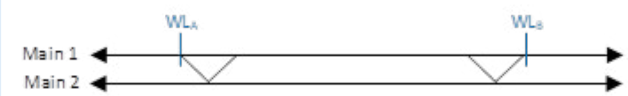
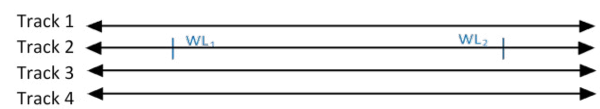
Use Case (UC) Set	Set Title	Description
UC-RWP-500	Roadway Worker ETO – Track Warrant Control Territory.	On-track protection of roadway workers or when roadway workers have exclusive occupancy authority in Track Warrant Control Territory
UC-RWP-600	Roadway Worker ETO – Centralized Traffic Control Territory	On-track protection of roadway workers when roadway workers have exclusive occupancy authority in Centralized Traffic Control Territory
UC-RWP-700	Track Bulletin	Protection of RW while working within limits of active Track Bulletin
UC-JOP-800	Joint Occupancy	Protection of roadway workers accessing track for which another group of roadway workers hold exclusive occupancy authority.

Track Configurations

It was recognized that each use case based on current operation practices could be expanded to different track configurations. TTCI developed a subsidiary list of possible track configurations that a transit rail roadway worker could expect to encounter, as shown in Table 8-2 and Appendix C.

Table 8-2 *Track Configurations*

Track Configuration	Description	Schematic
Single track	Single mainline track with no switches	
Single track with uncontrolled spur track	Single track with mainline switch providing access to uncontrolled (non-dispatched) spur track	
Single track with diverging mainline	Single track with mainline switch providing access to diverging mainline track	
Single track with siding	Single track, but with two mainline switches bounding work zone and providing access to siding	

Track Configuration	Description	Schematic
Double track	Two parallel mainline tracks with no switches	
Double track with single crossovers	Double track with single crossovers bounding work zone that allow movement between two mainline tracks	
Double track with universal crossovers	Double track, but with eight mainline switches, two sets in 'V' (universal) configuration, bounding work zone that allow movement between two mainline tracks	
Triple track	Three parallel mainline tracks, with two tracks to one side of track defined to have work zone, with no switches	
Quad track	Four parallel mainline tracks, one or two tracks on either side of track defined to have work zone, with no switches within work area.	
Complex configurations	Most seen in entrances/exits to yards or mechanical facilities, major junctions, or major terminals;[20] typified with multiple tracks, numerous switches, complex and confusing track arrangements	

Each of these track configurations carries with it differing risk levels. Elements such as additional tracks or the presence of crossovers or switches add complexity to the RWP scenario considered. The hazards expected in a single main environment are very different from those considered in a complex configuration such as a major junction or interlocking.

Track Construction Type

It was determined that type of track construction can be a factor in RWP and should be considered as part of the use cases. Based on feedback, several common transit track construction types were considered, as described in detail in Appendix C.

Predetermined place of safety (PPOS) is a readily-accessible location next to a track that roadway worker(s) are fouling but cannot be struck by a train. Moving

[20] RAIB, 2009, Accident at Dalston Junction, Department of Transport, November.

trains create a dynamic envelope around the operating train. It is not possible for a roadway worker to be struck by a train unless they are physically fouling the dynamic envelope within the track environment where a train may pass. Many agencies publish booklets showing PPOSs and sections of track that require foul time authorization because of lack of a PPOS.

RWP Use Cases

RWP use cases based on track protection, track configuration, and track construction were developed together with an assessment of steps to ensure roadway worker safety. Use cases define scenarios in which processes are executed without error and system failures that have not occurred. All use cases developed in this research are described in Appendix C. An example of a use case scenario incorporating all the elements of RWP is shown in Table 8-3, which also is found in Appendix C.

Table 8-3 *Example Use Case – Watchman/Lookout Single Track*

ID	UC-RWP-201
Title	Watchman/Lookout Protection (WLP) – Single Track
Description	Roadway workers under same WLP must foul main track to perform adjustments and/or repairs. Train on main track approaches work area.
Method of Operation	Any
RR Personnel	EIC, watchmen/lookouts, roadway workers, train operator
RR Systems	Transit train
Reference Track Configuration	Single track per Appendix C
Initial Condition	1. EIC determines maximum train speed approaching work area. 2. EIC determine sight distance available. 3. EIC determine sight distance required using speed/ sight distance table. 4. Watchman/lookout to obtain clear time estimate from EIC. 5. EIC briefs WLs and roadway workers on conditions (i.e., train speed, clear-to location(s), etc.) 6. Watchman/lookout to get in appropriate position to watch for trains and to alert roadway workers of approaching trains. 7. Main track to be accessed by roadway workers is unoccupied by train or other vehicles. 8. Roadway workers access track and begin work.
Trigger Event	Train approaches track segment occupied by roadway workers.
Scenario Steps	1. Watchman/lookout observes Train approaching. 2. Train operator observes roadway workers and blows whistle. 3. Watchman/lookout alerts roadway workers of approaching train. 4. Roadway workers clear track to PPOS, including any tools that may be in foul. 5. Train proceeds through track segment.
End State (Happy Path)	1. Watchman/lookout and roadway workers cleared all tracks. 2. Train proceeds.

Hazard/Risk Assessment

This section demonstrates how to evaluate the hazards/risks associated with the use case example presented in Table 8-4 using the hazard/risk assessment matrix developed in this research. First, the user (roadway worker) needs to select the hazard modifiers based on the conditions of the use case. For this example, the following additional conditions are assumed:

- Two-person roadway worker group intending to use watchman/lookout protection
- Single mainline with bi-directional traffic
- Traffic headway frequent

The user selects the other variables based on the working conditions expected to be encountered, as shown in Table 8-4.

Table 8-4 *Hazard Modifiers Selected by Roadway Worker*

Hazard Modifiers	
Speed	Maximum authorized
Sight Distance	Restricted – less than 0.25 mi
Clearances	Not available or too far away
Number of tracks	Single bidirectional
Switches	No
On-track equipment	Single hi-rail
Type of work	Minor non-disruptive
Ambient Noise Level	Minimal
Hand Tool Noise	No

To fully evaluate this use case, the roadway worker must also select human PSFs based on the current physical and mental state of the working group. If it is assumed that the working group is to perform a moderately complex task and have a good training background and good job aids available to them but have worked several overtime shifts recently and are stressed, the PSFs for this scenario would be similar to those shown in Table 8-5 (see Appendix B).

Table 8-5 *PSFs Selected by Roadway Worker*

Human PSFs	
Available time	Nominal
Stress State	High
Complexity	Moderate
Experience/Training	Nominal
Job Aids	Not available

Human PSFs	
Fitness for Duty	Degraded fitness
Work Processes	Nominal

The hazard assessment matrix output based on the variables selected in Table 8-4 and Table 8-5 is shown in Table 8-6. For the selected method of protection (i.e., watchman/lookout and traffic headway are frequent), this scenario shows undesirable risks that have not been fully minimized (orange).

Table 8-6 *Baseline Hazard Assessment for Use Case Example*

	HAZARD LEVEL	HAZARD LEVEL	HAZARD LEVEL
PROTECTION	SEVERE	SEVERE	SEVERE
Watchman/Lookout			
ETO			
Track OOS			

However, if an additional safety measure such as a secondary warning device system is used, then the hazard assessment matrix output is modified accordingly. The new hazard assessment is shown in Table 8-7. The use of a secondary warning device leads to a reduction in risk in multiple scenarios but causes the example scenario to go from being undesirable to acceptable (yellow; see color legend in Table 7-13) if extra caution is used.

Table 8-7 *Revised Hazard Assessment Using Secondary Warning Device*

	HAZARD LEVEL	HAZARD LEVEL	HAZARD LEVEL
PROTECTION	SEVERE	SEVERE	SEVERE
Watchman/Lookout			
ETO			
Track OOS			

Section 9

Concept of Operations for RWP Safety System

Benefits of RWP Safety System (Secondary Warning Devices)

Most agencies have instituted RWP policies and procedures as part of their RWP program and require that roadway workers complete initial and recurring on-track safety training and railroad operating rules training before being allowed to perform work. Even with appropriate training, there is potential for safety events and occurrences. To identify the hazards associated with roadway workers, a hazard/risk analysis should be conducted that can identify hazards still present to roadway workers even when following all rules and training. After evaluating safety risks, mitigations may be developed to lessen risk, which may include use of secondary warning devices.

Beyond normal RWP program elements, secondary protection of roadway workers can be achieved by incorporating technologies that prevent potential roadway worker hazards, especially for the following four categories:

- **Miscommunication** – This hazard could be minimized by an RWP safety system that can identify the exact location of each roadway crew member to the EIC (RWIC). See example in Appendix D.
- **Inattention** – This situation could be mitigated by the watchman using the Train Approach Detection Concept described in Appendix D. The train alert sent from such a safety system would allow roadway workers enough time to clear the track before arrival of the train.
- **Incorrect ITD Assessment** – Individual train detection situations could be mitigated by an RWP safety system by providing the exact location of a train to a lone worker before they enter the track foul limits. See example High Accuracy Train Location in Appendix D.
- **Workman Incapacitated** – Although a RWP safety system may not be able to alert an incapacitated worker of a train approach due to their physical state, it may be able to provide information to the EIC indicating that the workman has not cleared the track by providing their GPS location. For example, if a roadway work crew is working under ETO and the authority is nearing its granted end time, the EIC will radio each work crew member to notify them to clear the track, and each workmen will then radio the EIC to confirm they have cleared the foul of the track. If a workman in a remote location is unable to answer the EIC's call to the clear the track, the Worker Position Monitoring concept could provide the GPS location of the incapacitated workman to the EIC to allow the EIC to more efficiently keep

track of workers and act more immediately if one fails to respond when a call to clear is made.

The addition of an RWP safety system (secondary protection devices) working in conjunction with established RWP safety training and rules has the potential to greatly enhance roadway worker situational awareness. With the use of several potential concepts, a safety system provides roadway workers with information about the position of trains and other roadway workers. It would also provide an additional means of communication between roadway workers. Alerts would give workers audible, visual, and physical alerts to make them aware of potentially dangerous situations. Table 9-1 is an overview of potential benefits of an RWP safety system. Risk reduction concepts are discussed in more detail in Appendix D.

Table 9-1 *Benefits of RWP Safety System*

Risk	Risk Reduction Concept	Benefit
Environmental conditions such as weather or time of day results in a reduction in sight distance not recognized by lone worker	Train Approach Detection Alarm	Workers provided additional audible, visual, physical notification of train approach, improving situational awareness and reducing occurrence rate of incident
Workman moves outside of working limits	Roadway Worker Position Monitoring	Roadway workers provided accurate location of working limits and alerted when encroaching upon them
Watchman fails to notice train approaching due to inattention	Train Approach Detection/ Watchman Warning System	Watchmen/workers provided additional audible, visual, physical notification of train approach; watchman/worker communication enhanced.
ETO issued with incorrect work limits	Train Position Concept	EIC provided access to information as input by Dispatch; EIC able to verify ETO entered as requested prior to occupying track
High-speed train approach on track A while roadway workman on Track B	High-Accuracy Train Position	Roadway workers provided with information about train approach on adjacent track; improved situational awareness.

CONOPS of RWP Safety System (Secondary Protection Devices)

In general, a proposed CONOPS for an RWP safety system is not a single system but a set of concepts intended to improve roadway worker safety by reducing specific risks. The intent of this CONOPS is to provide complementary information to roadway workers that will further enhance situational awareness when in situations identified by a primary hazard assessment (PHA). However, such a system as laid out in the CONOPS is not capable of passing all critical information to roadway workers. Because of this, this CONOPS should not be considered a fail-safe system; it is a non-vital collection of operational data accessible to roadway workers rather than a replacement of current roadway operating and safety rules. Because of this, current roadway operating rules must remain in place and continue to be followed.

The goal of these concepts is to decrease the level of risk determined from an assessment of each work scenario, from a level at which risks to the roadway work group are deemed unacceptable to a level at which the risk from these hazards has been minimized substantially and an added factor of safety has been included. The concepts considered are all secondary in nature; their application will be most beneficial in scenarios determined to have unacceptable risk levels and would be used primarily to overlay existing rules, policies, and procedures and provide a level of enhanced safety.

Four high-level concepts for an RWP safety system were developed that can supplement safety and operation rules and are described in Appendix D:

- Train Location Concept
- Train Approach Detection Concept
- Watchman Warning System Concept
- Roadway Worker Position Monitoring Concept

CONOPS Gap Analysis

Even with these safety concepts for operations potentially being developed and implemented by transit agencies, there is still no perfect solution to roadway worker safety. The following are the potential gaps that need further improvements.

Technology Limitations

In most cases, current secondary warning technology does not have the ability to determine which track approaching trains are occupying, leading to alerts/alarms that are not applicable to a roadway worker. Some systems also have limited ranges of coverage, which makes systemwide coverage with the technology somewhat cumbersome.

Incapacitated Worker(s)

The incapacitated workers issue is an unaddressed risk from the preliminary hazard analysis and may remain, even with implementation of the safety concepts and technologies discussed. Secondary warning technology can provide only advance warning to roadway workers and their location information. If a worker becomes incapacitated for any reason, a warning given by the system would not be acknowledged and help may not be provided in time, leading to the potential risk of a worker being struck by a train.

Non-compliance

Non-compliance issues are noted in multiple incident reports across the industry and remain a major issue. Roadway workers may ignore rules and procedures or the safety concepts outlined in this report, such as a secondary warning device alarm being ignored, which ultimately negates any benefit the system might provide and fails to minimize risks of trackside work.

Another potential pitfall of a secondary warning device is roadway worker complacency. If a roadway worker continually receives non-applicable warnings (due to system limitations discussed above), they may begin to simply tune out the warnings altogether, thus eliminating any safety benefit.

The most important way to combat non-compliance is with a strong and effective compliance program championed and driven by the combined efforts of supervisors and upper management at each transit agency.

Section 10 Summary and Findings

Research into and investigation of current practices in the transit rail industry revealed continued issues with roadway worker protection. Some hazards are unaddressed by existing technology and procedures/policies, and additional research and technological advancement are needed. Effective RWP programs should include safety rules, practices, and methods that may lead to improved roadway worker safety and operational efficiency.

Following are the major findings of this effort:

- 70% of respondent transit rail agencies are using, to varying extents, the FRA RWP regulations contained in 49 CFR Part 214, Subpart C – Roadway Worker Protection. Most programs cover ITD (lone worker) and train approach warning (watchman/lookout) protection methods.
- A literature review and NTD database review revealed several hazards that current rules and regulations do not fully address, including miscommunication, inattention, improper ITD assessment/application, and incapacitation.
- Incident reports documented multiple instances in which roadway workers were struck by a rail vehicle and a common causal factor was poor quality job safety briefings at different operational and organizational levels.
- A hazard/risk assessment matrix incorporating human factors and risk analyses based on various use cases and implementation of secondary RWP protection devices based on a high level CONOPS of an RWP safety system can help agencies to improve RWP significantly.
- Available RWP technologies are designed to provide additional warning to workers and train crews but they do not serve as primary protection. Overlaying these technologies may enhance RWP, thus reducing safety risk.
- Additional RWP technology advancements and future research are necessary for further equipment and combined operational improvements.

Appendix A Roadway Worker Protection Industry Survey

Survey of Maintenance of Way (MOW) and Roadway Worker Protection (RWP) Procedures

The Transportation Technology Center, Inc. (TTCI) is conducting research to examine current practices and new and emerging technologies that may be used to reduce injuries and fatalities to transit rail roadway workers. TTCI developed this survey to gather information on roadway worker protection (RWP) current practices and technologies deployed or being tested by rail transit agencies. The survey includes input from rail transit agency safety officers and APTA. APTA is facilitating the survey response on behalf of the rail transit industry. The information gathered will be used to aid in development of high-level concepts of operation, recommended practices, and/or guidance resources that can be adapted industry wide.

TTCI seeks RWP program information across multimodal operations. If an agency, for example, has light rail, heavy rail, and/or trolley/streetcar operations, we request responses that address RWP procedures and technologies used across each of these methods of operation.

Your assistance with this research effort will lead to greater safety and knowledge across the transit industry. Thank you very much for your time and assistance on this matter.

Maintenance of Way (MOW) Evaluation

Organization Name:	
Name(s):	
Phone(s):	
Email(s):	

Rules and Regulations

		Yes	No
1.	Does your agency have a formal MOW operating rules manual or a set of Standard Operating Procedures?		
	If yes, please proceed to question #2. If no, please skip to question #5.		
2.	Is your agency's MOW operating manual based on another organization's publication or best practice documents/standards (e.g., NORAC, GCOR, another RTA or freight railroad)?		
2a.	If yes, please list all that apply. If no, please comment below how your agency's manual was developed.		

		Yes	No
3.	Has your agency adopted any part of FRA 49 CFR 214 Subpart C – Roadway worker protection? https://www.ecfr.gov/current/title-49/subtitle-B/chapter-II/part-214/subpart-C?toc=1		
3a.	If yes, please indicate below the portions of 214 Subpart C that have been adopted.		
4.	Does your agency's MOW Operating Rules manual contain a section(s) specifically covering Roadway Worker Protection?		
	If yes, please proceed to question #5. If no, please skip to question #6.		
5.	Can your agency provide copies of the RWP Worker Protection Operating Rules to produce an anonymized set of operating practices for eventual FTA and transit agency use? (THIS INFORMATION WILL BE KEPT CONFIDENTIAL.)		

Rail Network Information

		Yes	No
6.	How many route miles in your rail network?		
7.	Type and miles of track by miles that your organization is responsible to maintain: Single: Double: Triple: Quadruple: Sidings: Cross-Transfer Spurs: Yard:		
	Other (Explain):		
7a.	Type and percentage of rail transit operation within your organization?		
	Light Rail: Heavy Rail: Trolley/Streetcar:		
8.	Does any of your rail share or operate near other rail organizations lines?		
8a.	If yes, please name the organizations responsible for those lines and miles for each.		
9.	What kind of headways could a roadway worker expect to encounter while working in revenue service during peak and non-peak running hours?		

Roadway Work Protection Methods

		Yes	No
10.	Are all employees and contractors protected by the same forms of on-track safety?		
11.	Does your agency's program allow lone workers?		
11a.	If yes, list their functions.		
11b.	If yes, list protections/procedures (by reference) used for lone workers.		
12.	Does your agency's program allow for watchman/lookout protection?		
12a.	If yes, list their functions.		
12b.	If yes, list protections/procedures (by reference) used for watchmen/lookout protection		
13.	Does your agency's on-track safety program provide flexibility to add protection(s) based on the type of work being performed?		

		Yes	No
13a.	Please list the scenarios and protections.		
14.	Does the on-track safety program include provisions and procedures for multiple work groups working within a common work area?		
14a.	Do the multiple work groups use a single Roadway Worker in Charge (RWIC)?		
15.	Who can request working limits?		
16.	Who authorizes the requested working limits?		
17.	How are these limits documented and communicated (Site Specific Work Plan, Other – please list)?		
18.	Are any of the following NTSB recommended redundant protections in use on your agency's property?		
	Shunt devices: Train control system lockouts/tag-outs Positive stop devices 3rd rail power off verification tools Pwr. lock-out / Tag-out procedures/tools Wayside secondary warning alarm systems		
18a.	If yes, are any required under certain circumstances/conditions (please list)?		
19.	Is your agency using any RWP technologies to improve roadway worker protection that is not covered by the options in question #17?		
19a.	Please list the original equipment manufacturer(hardware) and system integrator (software/ application).		
20.	What does your agency consider to be fouling track? a. 4-ft from near rail b. 6-ft from near rail c. Encroaching the dynamic envelope d. 3-ft from near rail e. Other (metric from reference):		
20a.	Does your agency provide clearance platforms in areas that are difficult to clear up in?		
21.	How many seconds prior to the arrival of on-track equipment or trains do roadway workers have to be in a position of safety?		
22.	Are on-track equipment and revenue train traffic required to slow down when passing through areas where Roadway workers are known to be located?		
23.	Is there a requirement at your organization that roadway workers must acknowledge track equipment or revenue vehicle equipment movement through a work zone (i.e., waving through a train with reciprocal acknowledgement from the operator?)		
24.	Does your agency monitor compliance with your on- track safety program rules and regulations?		
24a	If so, how?		
25.	Does your agency have a process for addressing unsafe acts or conditions as reported by employees?		
25a	Please list.		
26.	Does your agency have a formal on track safety training program?		
26a	If yes, can you provide a copy of the training materials to TTCI's project manager Ben Bakkum? (THIS INFORMATION WILL BE KEPT CONFIDENTIAL.)		
27.	What in your opinion, is the greatest MOW risk(s) in priority order for accidents within your rail network?		
28.	What in your opinion, is the best MOW risk mitigation method used within your rail network?		

Appendix B

Quantifying and Assessing Potential Roadway Worker Hazards and Risks

Extensive research on human-machine system interactions can be found in the literature. The U.S. military and governmental agencies such as National Aeronautics and Space Administration (NASA) and the Nuclear Regulatory Commission (NRC) are among the entities that have published research efforts into the analysis of human-machine systems and how they fail. Most of the analysis focuses on the human element, which is applicable to railroad operating environments. RWP is, in the simplest sense, a system involving interaction between a mechanized element (the traffic, track, switches, and signal system) and a human element (the roadway worker or dispatcher/ rail traffic controller). The use of RWP consists of a series of complex sequences and points of interaction between the human element and the mechanical element of this system. Both elements (human and machine) can produce errors that impact the system and cause consequences of differing severity. Previous research[21] identified categories of human error that are not affected by the design over the overall system, i.e., how the human element interacts with the mechanized element to produce the desired outcome or end product for which the human-machine system was designed, as listed in Table B-1.

Table B-1 *Common Human Errors*

Slips: Attentional failures	Lapses: Memory failures	Mistakes: Rule- or knowledge-based
Intrusion Omission Reversal Mis-ordering Mis-timing	Omission of planned items Losing one's place Forgetting intentions	Incorrect application of "good rules" Application of "bad" rules Many types of knowledge-based mistakes

Study of this human element has been performed using the Cognitive Human Model (Figure B-1), which classifies the action of any human element in a system (for the purposes of this project, the roadway worker) as four subfunctions that are assisted using memory.

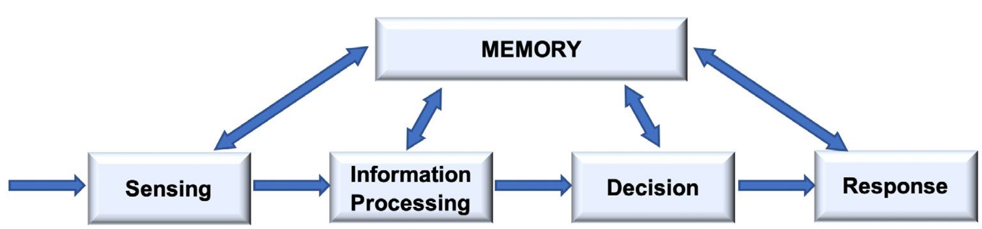


Figure B-1 *Cognitive Human Model*[22]

[21] U.S. Air Force Research Laboratory, 1998, *Electronic Reliability Design Handbook*, MIL-HDBK-338B, Department of Defense, 1 Oct. 1998.
[22] *Ibid.*

In the case of roadway workers, assuming that the cognitive human model is used to assess how they interact with the greater system (RWP), research has shown that there are numerous factors that impact the reliability of the human interaction with the system. These factors can be both internal and external and are shown in Figure B-2.

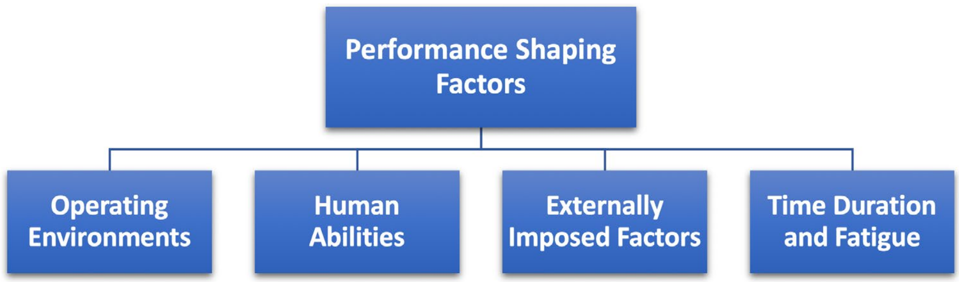


Figure B-2 *Factors that affect human function reliability*[23]

Research performed by the U.S. military[24] has shown that for each of these factors there are regions within in which performance is impacted by changing conditions. The classic railroad industry example of sight distance illustrates this concept. Sight distance can be limited by any of the factors from Figure B-2—for example, operating environment (weather) or an externally-imposed factor (arrival of new or unexpected workers who join task). Consider the impact of weather on the human element's performance (roadway worker serving as a watchman/lookout)—as the weather changes, the performance of the watchman/lookout will fall into one of the following regions:

- Reliable performance not degraded at all (weather does not impact vision)
- Reliable performance starts to degrade (weather starts changing and impacts vision)
- Reliable performance ceases all together (weather is so poor that reliable vision is not possible)

Failure by the human element (watchman/lookout) to conduct any of the actions in Table B-2 could potentially lead or contribute to human error.

Table B-2 *Potential Subfunction Actions That Could Cause Human Error*

Subfunction	Action
Sense	Any of five major senses detect the following: weather is changing (clouds roll in, fog thickens, thunder crashes, rain falls)
Process	Roadway worker thinks to himself/herself: "The weather is not what it was earlier."
Decide	Roadway worker makes decision: "Do I need to change my protection?"
Respond	Roadway worker acts: Makes the necessary change and informs the work group

[23] *Ibid.*
[24] U.S. Army Aviation and Missile Command, 1999, Department of Defense Design Criteria – Human Engineering, MIL-STD-1472F, Department of Defense, 23 Aug. 1999.

Failure to sense that the weather has suddenly changed and continuing to use watchman/lookout protection for a roadway work group would be classified as an incorrect application of "good" rules.

This, however, is an idealized approach to how this type of scenario might unfold. In actuality, the Cognitive Human Model fails to truly consider stimulus response and, more importantly, reflexive behaviors, i.e., a stimulus occurs and a human reacts reflexively. Newer models, such as SPAR-H, which was studied extensively by the U.S. Nuclear Regulatory Commission, have been designed to quantify the impact of the different performance shaping factors.[25] The goal is to try to prevent a human error that has serious consequences. Thus, the subfunction actions in Table B-3 are categorized into specific performance shaping factor categories and then are given a performance shaping factor (PSF) modifier based on the current state of that factor to quantify whether the subfunction will positively or negatively contribute to the outcome of an action executed by the human element of the system. Some typical PSFs are shown in Table B-3.

Table B-3 *PSFs and Example Modifier Values*[26]

PSF	Level	Example Modifier Value
Available time	Inadequate time	100
	Just enough time	10
	Nominal	1
Stress and Stressors	Extreme	50
	High	25
	Nominal	10
Complexity	High complexity	50
	Moderate complexity	25
	Nominal complexity	1
Experience and training	Low	10
	Nominal	1
	High	0.25
Procedures (including job aids)	Not available	100
	Incomplete	50
	Available, but poor	25
	Nominal	1
Ergonomics and human-machine interface	Missing/misleading	100
	Poor	50
	Nominal	1
	Excellent	0.25

[25] Gertman, D. I., et al., 2005, The SPAR-H Human Reliability Analysis Method, U.S. Nuclear Regulatory Commission.
[26] *Ibid.*

PSF	Level	Example Modifier Value
Fitness for Duty	Unfit	100
	Degraded fitness	50
	Nominal	1
Work Processes	Poor	25
	Nominal	1
	Excellent	0.75

Performance-Shaping Factors

Specific PSFs[27] that can be applied directly to the transit rail industry, specifically RWP, include the following:

- **Available Time** – generally describes the amount of time granted to an employee by a dispatcher or rail controller to complete a task in the field. Work windows granted are not universal, so time can play a large factor for PSF. The differences between these PSFs are described as follows:
  - Inadequate time – if the employee cannot safely complete the task no matter what they do
  - Just enough time – if the employee can complete the task using the full amount of time allocated to them by the dispatcher or rail controller
  - Nominal – the employee can complete the task with time to spare
- **Stress and Stressors** – can include things such as mental state, excess workload, and physical stress caused environmental factors such as excess heat or rain—factors that can impact any decision/action the employee faces in the field. The differences between these PSFs are described as follows:
  - Extreme – stress that will cause rapid, drastic performance deterioration
  - High – elevated level of stress characterized by things such as multiple unexpected alarms, sudden change in working conditions (plan did not work as intended or a tool breaks suddenly)
  - Nominal – stress state that does not negatively impact otherwise good performance
- **Complexity** – how difficult it is for the task at hand to be completed. Generally, the more difficult the task, the higher the opportunity for human error to occur. The differences between these PSFs are described as follows:
  - Highly complex – very difficult to perform, with many variables involved
  - Moderately complex – somewhat difficult to perform, several variables involved
  - Nominal – not difficult to perform, single or few variables involved

[27] *Ibid.*

- **Experience and Training** – training level and years of experience of the employee attempting the task. Generally, employees with better training and more years of experience are less likely to make human errors. The differences between these PSFs are described as follows:
  - Low – less than six months of experience, training level does not provide the necessary knowledge or understanding to adequately perform task
  - Nominal – more than six months, but less than five years of experience, training level is adequate for successful completion of day-to-day tasks
  - High – Five years or more experience, training level is extensive, and employees are proficient in all day-to-day tasks, and have been exposed to many different abnormal scenarios or tasks
- **Procedures (Job Aids)** – refers to the presence or availability of standardized procedures that outline proper execution of the task to be performed. These could include Standard Operating Procedures (SOPs) or Maintenance of Way Instructions (MWI) that describe a step-by-step process for a specific task or activity commonly performed by roadway workers. It should be noted that these job aids are considered supplements to the existing operating rules or procedures used by the agency. Differences between these PSFs are described as follows:
  - Not available – procedure/job aid for the task is not available or does not exist
  - Incomplete – procedure/job aid exists, but information that is need to completed task is missing
  - Available, but poor – procedure/job aid exists, but it contains incorrect, inadequate, outdated, or ambiguous information
  - Nominal – procedures/job aid exists and enhances performance of task by roadway worker
- **Fitness for Duty** – the physical and/or mental condition of the employee as impacted by conditions like fatigue, sickness, drug use, personal problems, or distractions. The differences between these PSFs are described as follows:
  - Unfit – employee is unfit to perform duties due to extreme fatigue or illness that has severely degraded mental capacity/performance
  - Degraded fitness – employee can perform duties, but the performance is notably degraded
  - Nominal – employee can perform duties with no decrease in performance quality
- **Work Processes** – the organizational aspects of inter-department function between departments or groups at the transit agency. It includes things like work planning, communication of those plans, and management or support when changes occur. The differences between these PSFs are described as follows:

- Poor – communication between groups is poor, work planning is inadequate and task performance is negatively affected
- Nominal – communication between groups is good, work planning is done with most parties involved in advance and task performance is not negatively affected
- Excellent – communication between groups is excellent, work planning is done with all parties involved well in advance and task performance is positively affected

Modifying Figure B-2 to incorporate these specific factors and the PSF modifiers in the analysis of potential errors and risks/hazards in the roadway worker decision process results in Figure B-3.

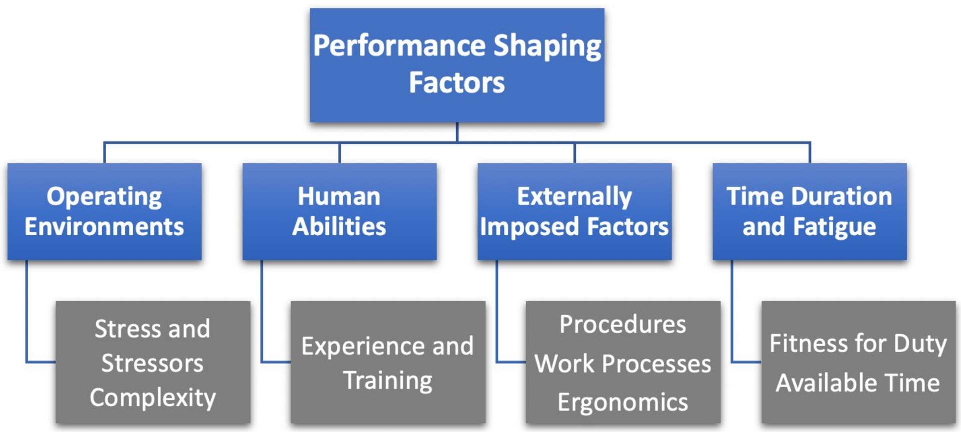


Figure B-3 *Expanded factors that influence human function reliability*

Assessing Potential Hazards and Risks

Understanding that the human-machine system is prone to error, especially from the human element (i.e., roadway worker), requires some method to manage the potential risks and hazards that can cause these errors. Multiple agencies have instituted risk management programs to minimize any negative influencing performance shaping factors. Some minimizing can be accomplished simply by having well-developed policies and procedures in place for work processes. Rail agencies accomplish this through operating rules that dictate when and how track protection must be applied for transit roadway workers. SOPs and job aids combined with rigorous and effective training programs are other ways to decrease the potential negative performance shaping effect on roadway workers. However, even with all these efforts,) a large portion of PSFs from Table B-3 remains. For example, how does an agency address an issue like available time (or lack thereof)?

NASA developed and implemented a process known as Continuous Risk Management (CRM) for all processes designed in part to mitigate by anticipating and proposing acceptable alternatives to unexpected high-risk events before they occur. NASA defines risk as a combination of the following three elements:

- The scenario(s) leading to degraded performance with respect to one or more performance measures (e.g., scenarios leading to injury, fatality, destruction of key assets; scenarios leading to exceedance of mass limits; scenarios leading to cost overruns; scenarios leading to schedule slippage).
- The likelihood(s) (qualitative or quantitative) of those scenarios.
- The consequence(s) (qualitative or quantitative severity of the performance degradation) that would result if those scenarios were to occur.[28]

The CRM method consists of five sequential steps to address the elements above as they arise, as shown in Figure B-4.

Figure B-4 *NASA Continuous Risk Management Process*

The process is bolstered by communication and documentation that can be considered integral to every step of the process. There is a separate, but equally as important, partner function to the CRM process that NASA defines as Risk-Informed Decision-Making (RIDM). RIDM is a preliminary process, the goal of which is to identify potential alternative solutions to a hypothetical scenario with a negative outcome. This first step in assessing and eventually minimizing risk is done prior to any plan being executed. The output of this RIDM process is a suitable alternative solution for which the risk(s) present are acceptable. When this alternative solution is implemented, the CRM process picks up to ensure that no other unaddressed risks present themselves at any time during the process.

Safety Management Systems

The processes and procedures described as part of RIDM and CRM systems give a broad overview of how risks can be identified and tracked, and, to a degree,

[28] Dezfuli, Homayoon, et al., 2011, *NASA Risk Management Handbook*, National Aeronautics and Space Administration.

how these risks are responded to. The next evolutionary step, following RIDM and CRM, is what is known as a safety management system (SMS). The NTSB defines a SMS as a comprehensive approach to establishing, implementing, and maintaining safe work practices, given the variability and diversity of jobs and personnel involved in complex systems such as railroads or rail transit agencies.[29] According to NTSB, hazard recognition is a fundamental cornerstone of any SMS, and three methodologies are highlighted for identifying hazards listed as follows:

- Predictive – hazard identification and mitigation
- Proactive – peer to peer safety responsibility
- Reactive – accident investigations

All three methodologies play a vital role in addressing workplace hazards for transit roadway workers; however, the first two are especially important for minimizing harm to transit roadway workers and are discussed further.

Predictive Hazard Recognition

NTSB identifies predictive hazard recognition as the optimum approach for hazard identification and defines the process as identifying any possible hazards before the work tasks begin through the use of a thorough and complete job briefing, including analysis of the task to be performed along with hazard recognition and mitigation. NTSB further states:

> Hazards are an inevitable part of the railroad and rail transit activities. However, they can be mitigated to minimize their consequences or outcomes if they are clearly identified. Comprehensive job briefings that identify the hazards related to the work task, including not only the hazard of train and other on-track equipment strikes, but also those that include natural hazards, falling hazards, bucket lifts, and others are vital to maintaining a positive safety culture within an organization.[30]

Proactive Hazard Recognition

Proactive hazard recognition involves analyzing existing situations for hazards. NTSB specifically recommends peer-to-peer safety responsibility as a form of proactive hazard recognition, which is the concept that each individual roadway worker has the shared responsibility of not only their own personal safety, but the safety of their coworkers. As NTSB explains:

[29] NTSB, 2014, Special Investigation Report on Railroad and Rail Transit Roadway Worker Protection, NTSB/SIR-14/03.
[30] *Ibid.*

> When employees are assigned tasks that endanger themselves or other employees or are observed performing task in a manner that endangers themselves or other employees, their coworkers should intervene and not let peer pressure or potential negative repercussions, such as criticism from coworkers or management, stop interventions to ensure tasks are completed safety.[31]

Both predictive and proactive methods of hazard recognition involve an employee taking an active role in determining hazards of any planned wayside work activity and taking the most appropriate safe course of action to protect themselves and their fellow roadway workers. One common approach seen in various applications of a CRM solution is the concept of a hazard assessment matrix. This matrix is essentially a tool, available to the roadway worker and others within the organization, that enables them to evaluate the hazards associated with various scenarios based on criteria including but not limited to:

- Probability of an incident or undesirable event occurring
- Severity level associated with the incident or event

By coupling the likelihood of an incident (probability) with a severity level, an employee can perform a quantitative assessment on how much risk the scenario being evaluated poses and whether their planned course of action will properly address and mitigate those risks.

[31] *Ibid.*

Appendix C

Roadway Worker Protection (RWP) Use Cases

1. Introduction

The objective of this document is to identify use cases that involve transit rail roadway worker protection (RWP). Use cases define scenarios in which processes are executed without error and system failures that have not occurred. These use cases will be used as the basis for the development of a high-level concept of operation (CONOPS) for a system that will enhance RWP. In addition, these use cases can be benchmarked by transit agencies to identify most significant hazards encountered by roadway workers in the transit rail operation environment and improve their RWP policies and procedures.

The use cases describe transit rail current operating practices and scenarios associated with establishing and maintaining RWP. In general, use cases included in this report represent base cases that can be used for hazard and risk analysis.

RWP defines and describes the practices and procedures used to protect transit roadway (Maintenance of Way, MOW) workers and their equipment from being struck by transit trains while at the same time protecting trains from work that disturbs the track, making it unsafe for the passage of trains and the personnel and equipment used to perform that work.

2. Basis for Concepts

For this document, FRA Part 214 Railroad Workplace Safety and Subpart C, Roadway Worker Protection[32] regulations and its companion documents (Compliance Manuals, Technical Bulletins, Emergency Orders, Safety Advisories, Directives)[33] are heavily relied upon for basis and comparison. Unlike the North American heavy rail systems (both freight and transit), for which the requirement for interoperability lends itself to "one size fits all" generic regulations, transit systems do not have these interoperability requirements, and many are quite different from each other.

The first sentence of the FRA's RWP regulations states that "The purpose of this subpart is to prevent accidents and casualties caused by moving railroad cars, locomotives or roadway maintenance machines striking roadway workers or roadway maintenance machines."[34] The regulations in Section 214.7 define "on-track safety" as "a state of freedom from the danger of being struck by a moving railroad train or other railroad equipment, provided by operating and

[32] 49 CFR Part 214, Subpart C.
[33] FRA eLibrary https://railroads.dot.gov/elibrary-search.
[34] 49 CFR § 214.301(a).

safety rules that govern track occupancy by personnel, trains and on-track equipment."[35]

RWP provides either positive protection from possible train movements or sufficient sight distance to detect trains and have sufficient time to get to a place of safety well before the train or on-rail vehicle arrives at their location (including without being trapped by physical obstacles or vehicle movements on adjacent tracks).

Although FRA's RWP regulations may not be directly applicable to rail transit agencies that are not connected to the general rail system of RTAs, their basic concepts can still apply.

3. Predetermined Place of Safety (PPOS)

Predetermined Place of Safety (PPOS) is a readily-accessible location next to a track that roadway worker(s) are fouling but cannot be struck by any train. Trains can occupy only the track they are on, so it is not possible for roadway workers to be struck by a train unless they are physically fouling a track where a train may pass. A PPOS is a location where there is sufficient space for roadway workers that can be accessed in sufficient time before a train arrives at their location.

3.1 Sufficient Time

Roadway workers need to be able to access the PPOS well in advance of a train reaching their location. Individual transit agencies have predetermined time limits to clear the track before the arrival of an approaching train; these limits are set as a minimum time to safely remove any equipment or roadway workers from fouling the track. The time provided to reach the PPOS must be more than the minimum required. Roadway workers should have sufficient time cushion to be comfortably in the PPOS well before the train passes them.[36]

3.2 Other Factors

The PPOS is used not only for safety from moving trains but for other situations as well. For example, on street running track, at or near road crossings, and within busy construction or industrial sites, roadway workers need to be protected from road vehicles and other passing equipment. In multiple track areas, even if the track roadway workers are on is the designated PPOS, they could be struck by a piece of their own equipment working on the protected track, as they might attempt to clear here when a train passes on a live adjacent track. Where there is vehicular traffic adjacent to the tracks, roadway workers need a PPOS where they will not be struck or trapped by passing vehicles.

[35] 49 CFR § 214.7.

[36] 49 CFR Part 214 requirements are that roadway workers must be able to move and occupy a PPOS not less than 15 seconds before a train moving at the maximum authorized speed on that track can pass the location of the roadway worker.

3.3 Sufficient Space

FRA requires that roadway workers be a minimum of four feet from the nearest rail to be in a PPOS when a train passes on that track. This may not directly apply to transit agencies.

Each RTA should assess the size of the various types of equipment that could pass roadway workers and determine the safe setback distance for their particular property. When making the determination, the worst-case dynamic positions of the vehicle(s) should be considered (see Figure C 1) and the additional space needed for the lateral offset of those vehicles when they are on curved track (see Figure C-2), including tipping from superelevated track (see Figure C-1). Where multiple vehicle types are in use, the worst cases should be used.

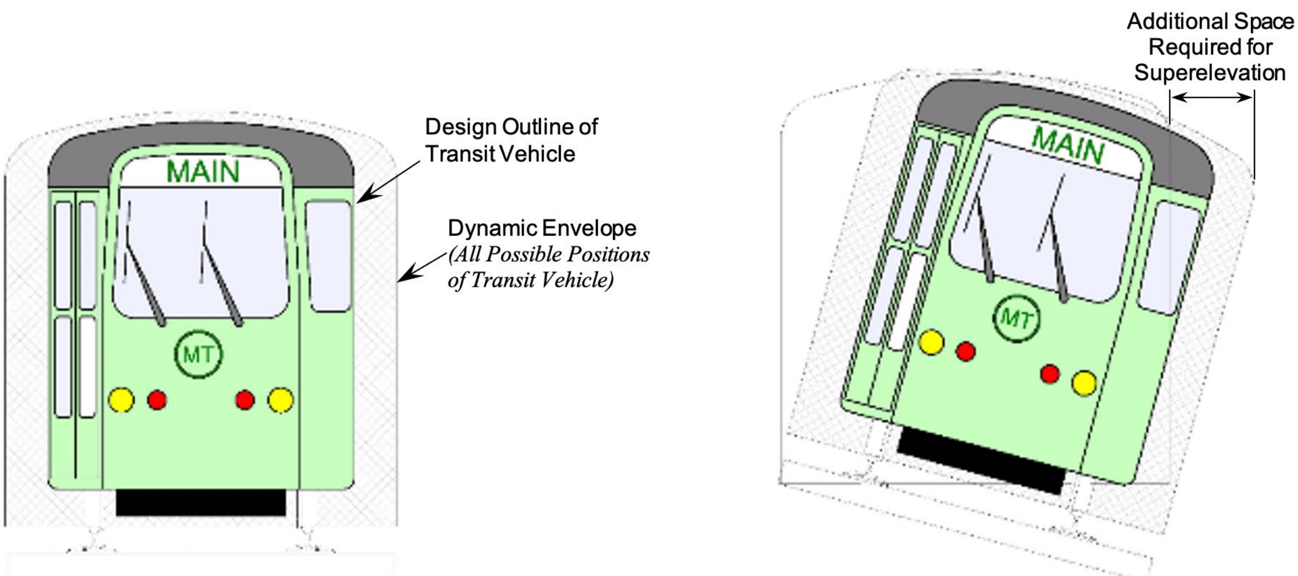


Figure C-1 *Dynamic envelope (left) and tipping from superelevated track (right)*

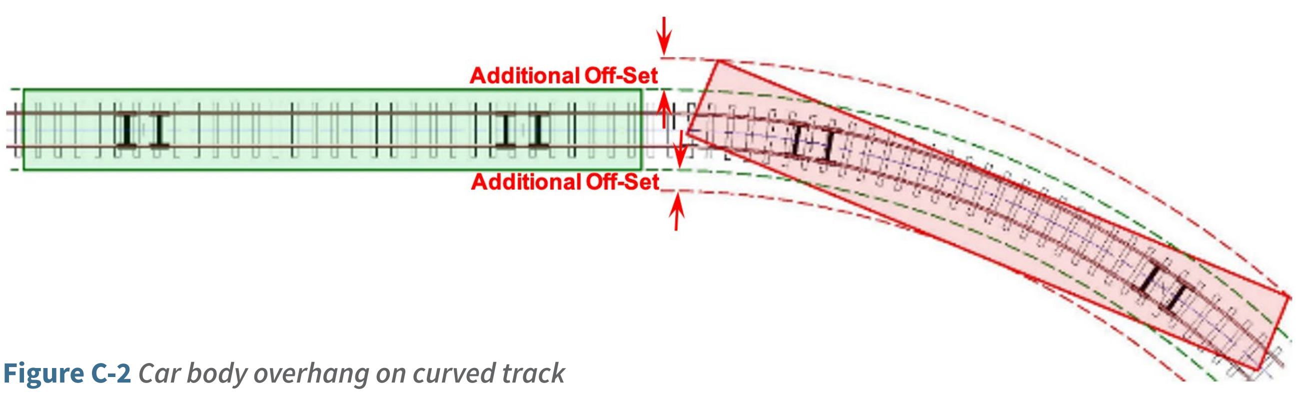


Figure C-2 *Car body overhang on curved track*

4. Use Case Description

The following use cases are grouped into sets, as shown in Table C-1, to aid in organization. Each use case is assigned an identifier that includes set membership.

Table C-1 *Use Case Sets*

Use Case Set	Set Title	Description
UC-RWP-100	Lone Worker	On-track protection for a Lone Worker (LW) who does not have formal exclusive track authority from a Dispatcher
UC-RWP-200	Watchman/Lookout	On-track protection for a group of RWs who do not have formal exclusive track authority from a Dispatcher
UC-RWP-300	Acquisition of Exclusive Authority to Access Track	RW or RW gang exclusive or joint authority to access track from a Dispatcher
UC-RWP-400	Train Coordination	RW on-track protection when an exclusive track authority is ceded by TO to an EIC
UC-RWP-500	Roadway Worker Exclusive Track Occupancy – Track Warrant Control Territory	On-track protection of RW or when RW have exclusive occupancy authority in Track Warrant Control Territory
UC-RWP-600	Roadway Worker Exclusive Track Occupancy – Centralized Traffic Control Territory	On-track protection of RW when RW have exclusive occupancy authority in Centralized Traffic Control Territory.
UC-RWP-700	Track Bulletin	Protection of RW while working within limits of an active Track Bulletin
UC-JOP-800	Joint Occupancy	Protection of RW accessing track of which another group of RW hold exclusive occupancy authority

Use cases in this document are described using a common format, as shown in Table C-2.

Table C-2 *Use Case Format*

Field Name	Description
ID	Unique use case identifier
Title	Name of use case
Description	Brief description of processes involved in the operating scenario
Method of Operation	Indication of applicable rail method of operation(s) rules. (e.g., CTC, TWC)
RR Personnel (Human Actors)	List of rail personnel involved in scenario, such as EIC, RW, TO, Dispatcher, etc.
RR Systems (Machine Actors)	List of rail systems involved in scenario, such as Train, TBTC, DBO, CAD, etc.
Reference Track Configuration	Generic track arrangement of use case
Initial Condition	Description of setup situation at start of scenario. Include state of RR systems, authorities in place, location of RR personnel, location of trains, etc.

Field Name	Description
Trigger Event	Action and actor that initiate described scenario; each step should be granular
Scenario Steps	Description of steps/actions/events of scenario in sequential order, and what actor performs each action
End State (Happy Path)	Description of the final disposition of actors and when scenario is successful
References	Identification of documents or sections of documents used to define use case

4.1 Reference Track Configurations

Reference track configurations define a basic set of use case track arrangements. Reference track configurations are intended to streamline use case definition by predefining generic track arrangements used. Additional details related to scenario conditions, such as position and movement of trains, are defined within the use case descriptions. All indicated tracks should be considered as controlled by a dispatcher unless otherwise noted. Conditions that contribute to errors or hazardous situations are examined in the hazard analysis and are not included in the use cases.

In scenarios with Exclusive Occupancy Authorities, the work zone is bounded by work limits (WKL) defined by:

- Mile posts, stations, switches, or other clearly identifiable locations with TB or TWC; and,
- Absolute signals, interlockings or control points, in CTC.

When a switch, interlocking, or CP is referenced as a WKL bound, the switch is not included within the work limits unless otherwise noted in the use case description. Additionally, in multi-track territory, it is assumed that track centers are less than 20 ft apart from adjacent track unless otherwise stated.

4.1.1 Single Track

Single mainline track with no switches within the scenario’s work zone.

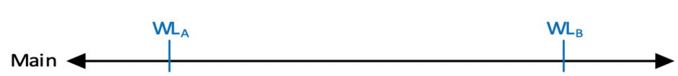


Figure C-3 *Single track*

4.1.2 Single Track with Uncontrolled Spur Track

Same as single track, but with a mainline switch providing access to uncontrolled (non-dispatched) spur track.

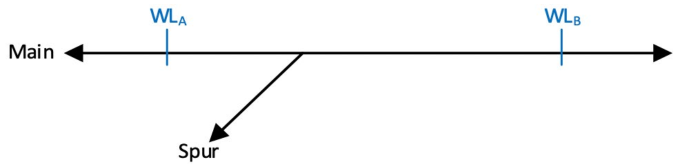


Figure C-4 *Single track with spur*

4.1.3 Single Track with Diverging Mainline

Same as single track, but with a mainline switch providing access to a diverging mainline track.

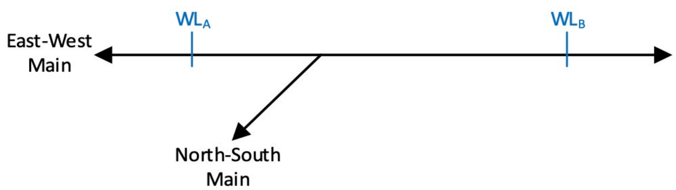


Figure C-5 *Single track with mainline divergence*

4.1.4 Single Track with Siding

Same as single track, but with two mainline switches bounding the work zone and providing access to a siding .

Figure C-6 *Single track with siding*

4.1.5 Double Track

Two parallel mainline tracks with no switches within the scenario's work zone.

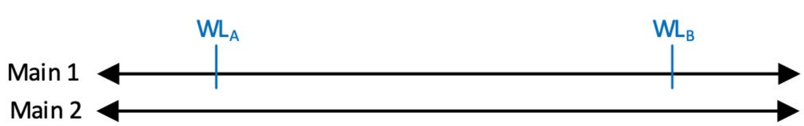


Figure C-7 *Double track*

4.1.6 Double Track with Single Crossovers

Same as double track, but with single crossovers bounding the work zone that allow movement between the two mainline tracks.

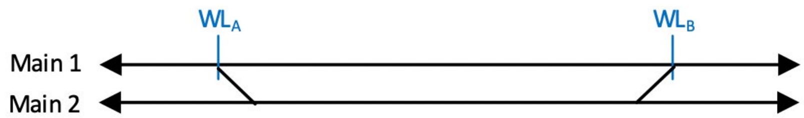


Figure C-8 *Double track with single crossovers*

4.1.7 Double Track with Universal Crossovers

Same as double track, but with eight mainline switches, two sets in 'V' (universal) configuration, bounding the work zone that allow movement between the two mainline tracks.

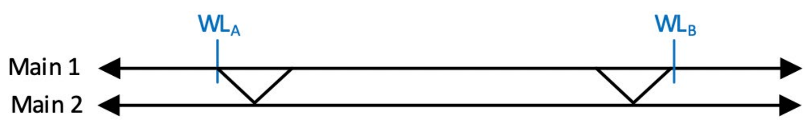


Figure C-9 *Double track with universal crossovers*

4.1.8 Triple Track

Three parallel mainline tracks, with two tracks to one side of the track defined to have a work zone, with no switches within the work area.

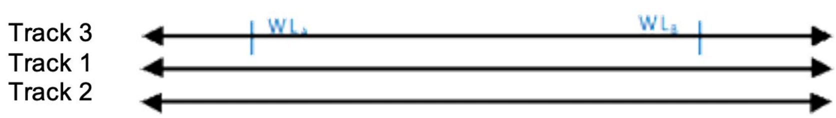


Figure C-10 *Triple track*

4.1.9 Quad Track

Four parallel mainline tracks, one or two tracks on either side of the track defined to have a work zone, with no switches within the work area.

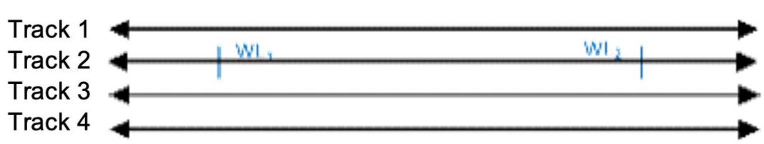


Figure C-11 *Quad track*

4.1.10 Complex Track Configurations

May exist on any system. These are most seen in entrances/exits to yards or mechanical facilities, major junctions, or major terminals. These are typified with multiple tracks, and numerous switches and complex and confusing track arrangements. These are highly site-specific MOW RWP must be reviewed on a case-by-case basis and very site specific within these areas examples of which are shown in Figure C-12.

Figure C-12 *Complex track configurations*

Other complex configurations, such as a five- or six-track configuration, are, in principle, the same as quad track configurations, where the inner tracks must be treated differently from outer tracks, as roadway workers would have to pass over live tracks to get to a PPOS.

In any case, the basic principles or RWP need to be applied, either positive protection from all possible train movements or sufficient distance to detect trains AND get to a place of safety without being trapped by movements on adjacent tracks.

For example, in the complex arrangement example in Figure C-13, it may be appropriate for a roadway worker to access the areas in green but not in red, or the roadway worker may be safe in the yellow areas but require additional protection to access those areas as shown in Figure C-13.

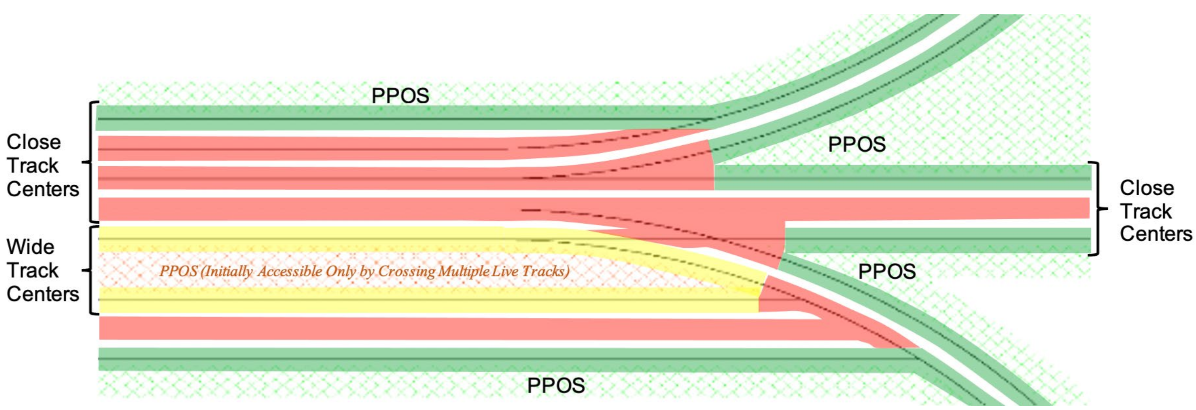


Figure C-13 *Complex track configurations*

5. Track Construction

Various track construction types affect the way use cases are applied. Although track configurations cover many use cases, track construction type affects the ability of roadway workers to detect oncoming track movement and get to a place of safety in a timely manner. Various track forms are generalized below, but the application of the use cases must consider other factors that impact roadway worker ability to detect oncoming trains. Therefore, the additional factors may require a more restrictive or adapted approach to RWP. For example, at-grade track that has walls or fencing installed along and close to the track may need to be considered more like u-wall or tunnel construction (see Figure C-14).

Figure C-14 *Vegetation and fencing limiting PPOS*

In any case, the basic principles or RWP protection need to be applied, either positive protection from all possible train movements, or sufficient sight distance to detect trains and get to a place of safety without being trapped by physical obstacles or vehicle movements on adjacent tracks. Although an attempt has been made herein to cover common track construction types, each situation should be assessed separately and the factors discussed below applied to the unique situations. For example, at-grade track that has a 6-lane bridge that covers 200 ft of track might be considered a tunnel for the purposes of RWP if the piers for the bridge adjacent to the track are so closely located that there is insufficient space for a roadway worker to clear the track(s) (e.g., Place of Safety) (Figure C-15).

Most modern rail transit system tracks are constructed with continuous walkways along each track to facilitate emergency evacuation of passengers. However, they may provide sufficient clearance only for people walking past a stopped train. Continuous walkways need to be reviewed to ensure that they provide sufficient space to be used as a PPOS by roadway workers when moving trains pass. The speed of passing trains should also be included in the review to ensure that transient air pressures from the passing trains do not affect the ability of roadway workers to maintain their safe position, particularly in tunnels or other enclosed areas.

Figure C-15 *Long overpass and walls limiting PPOS*

5.1.1 At-Grade Track

Typified by the track being built on the ground (grade). In some cases, it may be constructed on a fill (with or without retaining walls) or in a cut (see U-Wall Track Construction), as shown in Figure C-16. At-grade track typically provides continuous PPOS adjacent to outside tracks. However, at-grade tracks are subject to environmental conditions that can impact RWP including weather, visual distractions, and outside noise that can impact the ability of roadway workers from detecting approaching trains. Additional precautions must be used where tracks are located along or between roadways where approaching train movement can be masked by the movement and noise from vehicles on the adjacent roadways.

Figure C-16 *At-grade track*

5.1.2 Street Running Track

Constructed directly within public streets, and both road vehicles and trains share the right-of-way. In addition to the additional precautions that have to be taken with at-grade track, roadway workers must protect against road vehicle movements. In some cases, road vehicle traffic control must be applied. When working on Street Running Track, roadway workers must understand that motor vehicle operators may expect to see trains but not people and/or roadway equipment and can be easily confused by or may simply ignore MOW personel in the roadway working on or inspecting the track.

Figure C-17 *Street running track*

5.1.3 Road Crossings

Where roadways cross the tracks. In addition to added precautions that have to be taken with at-grade track, roadway workers must protect against road vehicle movements, keeping in mind that motor vehicle operators expect to see trains at road crossings and not MOW personnel. Even when automated warning systems are activated, drivers may be confused or ignore roadway workers or equipment on road crossings.

Figure C-18 *Public road crossings*[37]

5.1.4 Aerial or Elevated Track

Commonly called bridges on freight railways, constructed above the ground, limited in width, and seldom provide any extra space. Roadway workers working on aerial/elevated track must take extra precautions to ensure there is adequate space to use as a PPOS, and the limited space available for PPOS is accessible and not blocked by equipment or stored materials. Aerial/elevated track is subject to environmental conditions that can impact RWP protection, such as weather, visual distractions, and outside noise that can impact the ability of MOW workers from detecting approaching trains.

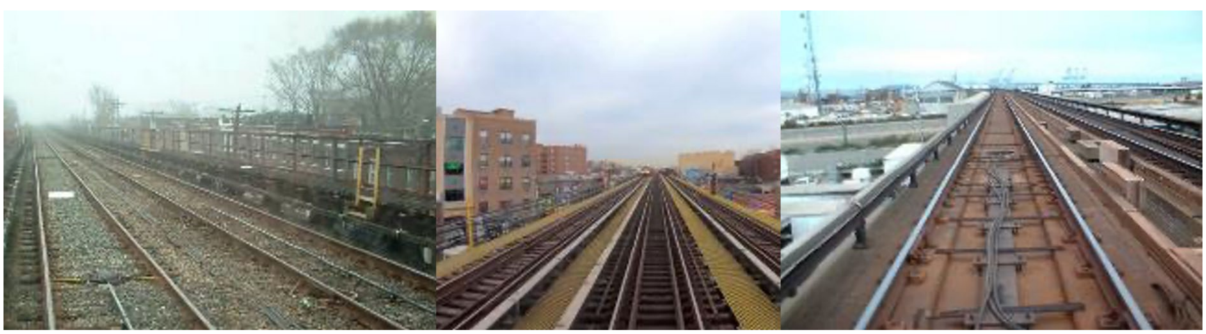


Figure C-19 *Aerial/elevated track*

5.1.5 Subway/Tunnel Track

Constructed underground and seldom has any extra space to be used as a PPOS. Roadway workers working on subway/tunnel track must take extra precautions to ensure there is adequate space to use as a PPOS and that the limited space available for PPOS is accessible and not blocked by equipment or stored materials. Subway/tunnel track is not subject to the typical environmental conditions that can impact RWP protection, such as

[37] Images from Valley Metro Regional Public Transportation Authority (RPTA) and Georgia Department of Transportation (GDOT).

weather, visual distractions, and noise that can impact the ability of roadway workers from detecting approaching trains. In some cases, detection of trains is improved, as roadway workers can sometimes better see/hear/feel trains approaching. However, sight distance can be impaired by horizontal or vertical curves, and roadway workers may not be able to detect which track is occupied by an approaching train. Extra precautions must be taken near ventilation shafts, as street noise, lighting differences, and fan noise may impact roadway workers ability to detect approaching trains.

Figure C-20 *Subways/tunnels*

5.1.6 Subway/Tunnel Portals

Found at the ends of subway and tunnels and can create additional hazards for MOW employees, as they considerably limit roadway worker ability to detect approaching trains. Noise from approaching trains is typically limited until the train passes through the portal. Also, the difference in lighting at portals may limit the ability to see approaching trains. Extra precautions must be taken by MOW Employees when fouling tracks in and around portal areas.

Figure C-21 *Tunnel portals*

5.1.7 U-Wall Track

Constructed in depressed areas, typically with retaining walls along each side of the track. This differs from a track cut, in that is constructed much like a tunnel without a cover. In most cases, RWP should be similar to that provided in tunnels. Unlike tunnels, U-Wall track has distractions that can limit the ability to detect trains of at-grade along with the restrictions typically associated with subway/tunnel tracks.

Figure C-22 *U-wall construction*

5.1.8 Station Platforms

Can create unique hazards to MOW workers in the trackway. Stations typically have many obstructions close to the track and have visual and audible distractions (e.g., public announcements). Although low platforms may provide a continuous PPOS along the platform side of the track, raised platforms may not be readily-accessible to allow MOW workers to clear the trackway quickly and reliably because of their height.

Figure C-23 *Station platforms*

5.1.9 Refuge Niches / Platforms

Provided where continuous walkways are not available adjacent to tracks occupied by roadway workers. As these platforms may be all that are available for clearing trains, extra precautions must be taken to ensure that they are accessible by roadway workers in sufficient time, have sufficient space for all the roadway workers, are not blocked by installed equipment or stored materials, and can be confirmed as not blocked, in advance of need for use.

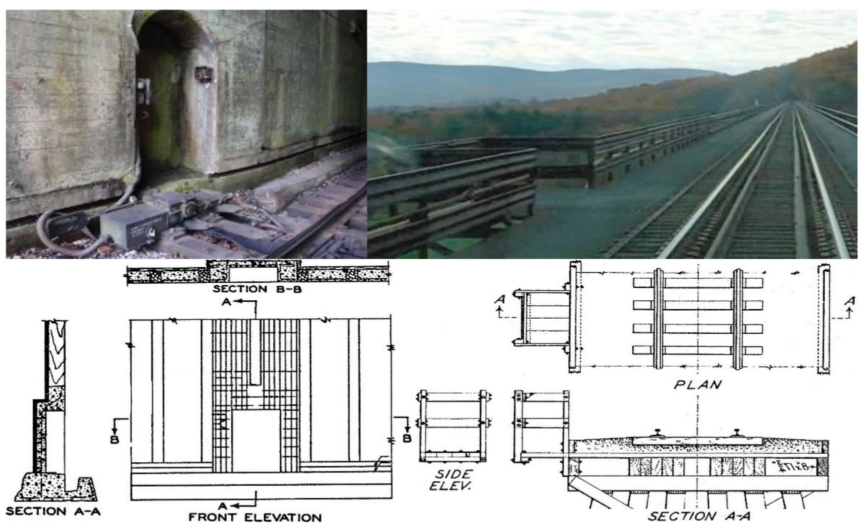


Figure C-24 *Refuge niches / platforms*[38]

5.2 Train Control Systems

Terminology used, bases, steps, and procedures needed to properly protect roadway workers are based on the train control systems or processes used.

[38] Drawings from Southern Pacific Railroad Standard Plans.

Although it is not possible to cover every unique system in use, those presented here are close parallels to many systems used and include common examples and their various use cases; examples and principals presented here can be adapted and applied. Although the terminology may be different among the various unique systems, the basic principles of RWP apply. RWP needs to be provided as needed for the site and situation, either positive protection from all possible train movements or sufficient distance to detect trains and get to a place of safety without being trapped by movements on adjacent tracks.

5.2.1 Autonomous and Remote Train Control

Some transit agencies use autonomous train control in their rail networks. Autonomous Train Control (ATC), Automatic Train Operation (ATO), or Remote Train Operation (RTO) are systems that may require additional considerations for RWP.

In these systems, the train control system controls the train. In the case of ATC, there may be no physical operator on board the train. For ATO systems, there may be an attendant on board the train but their involvement in the actual train operation may be limited to actions such as initiation of a run or delaying an automatic station stop to allow additional time for passengers to board the train while the operation of the train (speed control, stopping for conflicting movements, etc.), is handled by the train control system. Remote Train Operation (RTO) are semi-autonomous systems, where the train control systems operate the train and a remote attendant oversees the operation. In RTO systems, the attendant may be overseeing the operation of more than one train. Typically, types of systems are used in exclusive rights-of-way (no road crossings, no public access, and all access by personnel is controlled).

With these systems, for the purposes of RWP, the trains should be considered unaware of sudden changes to track conditions. Unlike manually-operated trains, in which a live person is operating the train and looking out for obstruction on the track ahead, these automated systems have no way of knowing if there are personnel on the track unless some form of intervention (protection) is applied directing the train to stop or slow. It is not typically possible for a MOW worker wayside to manually signal a train to stop.

In these systems, the same basic principles for RWP protection apply, and there are as many parallels to autonomous operations as there are for high-speed trains (where it can take thousands of feet to stop) or slow speed trains where there is limited visibility.

5.3 Rules for Use Case Development

Each use case is written at a specific level of system detail and with a certain set of rules in mind, summarized as follows:

- **Initial conditions** describe actors, actions, and circumstances that occur prior to the initiation of the scenario event. Whereas initial conditions are not part of the scenario events, they are essential for the complete understanding of the scenario. Each initial condition description is granular, defining a single condition, actor, and action. Each initial condition description is complete, defining a single actor/action pair, or location/condition.
- The **trigger event** defines the circumstance that initiates the scenario; its description defines the actor, action, and location of the trigger event.
- **Scenario steps** define the scenario actions of the use case in the sequence in which those actions occur. Each scenario step description is granular, defining a single actor and action. Each scenario step description is complete, defining a single actor/action pair.
- **Mechanical actors** within a use case are defined at the segment level or above. For example, "Dispatch Back Office (DBO)" is used to reference the set of functions associated with dispatching and track bulletin generation. This allows use cases to be defined at a level that is not dependent upon vendor specific product implementation.

Use case activities, objects, and actors are described in a generic manner, especially with respect to a specific rail's operating rules and practices. For example, "Roadway Worker (RW) has bulletin authority to access track" is used instead of "RW has Form B." This allows use cases to be defined in a manner that is independent of terminology or nomenclature that is specific to a railroad or set of operating rules.

Use cases define scenarios in which processes are executed without error and system failures have not occurred. Possible process errors, system failures, and their effects will be explored in a preliminary hazard analysis.

6. Use Cases

Assume for all adjacent tracks that track centers are less than 20 ft apart from adjacent track unless otherwise stated in scenario description. Where the term "train" is used, it is explicitly referring to a rail transit vehicle, unless stated otherwise. Use cases include examples of the basic track configurations most encountered on transit railroads:

- Single track
- Single track with uncontrolled spur track
- Single track with diverging mainline
- Single track with siding
- Double track
- Double track with single crossovers
- Double track with universal crossovers

These use cases have been developed to demonstrate methods of obtaining RWP in common situations. Situations with more complex track structure or unique hazards may require adaptation or layering of multiple RWP methods to ensure safety while performing MOW work tasks.

6.1 Lone Worker Use Cases

The Lone Worker (LW) use case set (UC-RWP-100) describes how a LW who does not have exclusive track occupancy authority from a dispatcher obtains and maintains on-track protection. Under the LW method of on-track protection, the single person is responsible for spotting approaching trains while performing other work tasks when fouling the track(s) with enough time to safely clear from the track. Requirements of LW protection are as follows:

- LW is trained and qualified to perform their tasks.
- LW must have sufficient sight distance in all directions along the tracks to provide a minimum warning time at least equal to the time required to safely clear of the track plus at least 15 additional seconds before trains reach their location.
- LW must be working in a location where their ability to detect approaching trains in a timely manner is not impaired by background noise, lights, precipitation, fog, passing trains, or any other physical conditions.
- LW may not engage in any activities, including work task(s) being performed, that will distract them in any way from self-protection.
- LW cannot be performing work in a control point or interlocking limits.
- LW can be performing work that is only “minor” in nature and does not affect the track structure, such as:
    - Retrieving or removing an item from the track
    - Lining track switches (manual and electric lock)
    - Placing or removing flags
    - Taking a single photo of an actual or suspected safety hazard using a camera device not capable of electronic communications (i.e., not a cellphone camera)
    - Visual inspection deemed an immediate need

The LW has sole authority to determine if this form of protection is adequate for the tasks being performed, with the given locations and conditions. Table C-3 provides a list of use cases in this series.

Table C-3 *Lone Worker (LW) Use Cases*

Use Case ID	Use Case Title
UC-RWP-101	Lone Worker – Single Track
UC-RWP-102	Lone Worker – Single Track with Uncontrolled Spur Track
UC-RWP-103	Lone Worker – Single Track with Diverging Mainline
UC-RWP-104	Lone Worker – Single Track with Siding
UC-RWP-105	Lone Worker – Double Track
UC-RWP-106	Lone Worker – Double Track with Single Crossovers
UC-RWP-107	Lone Worker – Double Track with Universal Crossovers

6.1.1 Lone Worker – Single Track

ID	UC-RWP-101
Title	Lone Worker – Single Track
Description	LW must foul main track to perform inspection or minor adjustment/repair; train on main track approaches work area
Method of Operation	Any
RR Personnel	LW, TO
RR Systems	Transit train
Reference Track Configuration	Single track per section 4.1.1.
Initial Condition	1. LW determines maximum train speed. 2. LW determines clear time and predetermined place of safety. 3. LW determines sight distance available. 4. LW determines sight distance required using speed/sight distance table. 5. Track to be accessed by LW is unoccupied. 6. LW accesses track and begins work if ITD is adequate.
Trigger Event	Train approaches track segment occupied by LW
Scenario Steps	1. LW observes Train approaching. 2. TO blows whistle. 3. LW clears track to PPOS. 4. Train proceeds through track segment.
End State (Happy Path)	1. LW cleared track. 2. Train proceeded.

6.1.2 Lone Worker – Single Track with Uncontrolled Spur

ID	UC-RWP-102
Title	Lone Worker – Single Track with Uncontrolled Spur Track
Description	LW must foul main track to perform inspection or minor adjustment/repair; train on uncontrolled spur approaches work area
Method of Operation	Any
RR Personnel	LW, TO

RR Systems	Transit train
Reference Track Configuration	Single track with uncontrolled spur per section 4.1.2.
Initial Condition	1. LW determines maximum train speed. 2. LW determines clear time and predetermined place of safety 3. LW determines sight distance available, including spur track. 4. LW determines sight distance required using speed/sight distance table. 5. Track to be accessed by LW is unoccupied. 6. LW accesses track and begins work if ITD is adequate.
Trigger Event	Train on spur track approaches track segment occupied by LW
Scenario Steps	1. LW observes train approaching. 2. TO blows whistle. 3. LW clears track to PPOS. 4. TO proceeds through track segment.
End State (Happy Path)	1. LW cleared track. 2. Train proceeded.

6.1.3 Lone Worker – Single Track with Diverging Mainline

ID	UC-RWP-103
Title	Lone Worker – Single Track with Diverging Mainline
Description	LW must foul east-west main track to perform adjustments and/or minor repairs; train on north-south main track approaches work area
Method of Operation	Any
RR Personnel	LW, TO
RR Systems	Transit train
Reference Track Configuration	Single track with diverging mainlines per section 4.1.3.
Initial Condition	1. LW determines maximum train speed. 2. LW determines clear time and predetermined place of safety. 3. LW determines sight distance available, to include diverging mainline. 4. LW determines sight distance required using speed/sight distance table. 5. Track to be accessed by LW is unoccupied. 6. LW accesses east- west main track and begins work.
Trigger Event	Train on north-south main approaches track segment occupied by LW
Scenario Steps	1. LW observes train approaching. 2. TO blows whistle. 3. LW clears track PPOS. 4. TO proceeds through track segment.
End State (Happy Path)	1. LW cleared track. 2. Train proceeded.

6.1.4 Lone Worker – Single Track with Siding

ID	UC-RWP-104
Title	Lone Worker – Single Track with Siding
Description	LW must foul siding track to perform inspection or minor adjustment/repair; train on main track approaches work area
Method of Operation	Any
RR Personnel	LW, TO
RR Systems	Transit train
Reference Track Configuration	Single track with siding per section 4.1.4.
Initial Condition	1. LW determines maximum train speed. 2. LW determines clear time and predetermined place of safety. 3. LW determines sight distance available, to include siding. 4. LW determines sight distance required using speed/sight distance table. 5. Siding track to be accessed by LW is unoccupied. 6. LW accesses siding track and begins work if ITD is adequate.
Trigger Event	Train on mainline approaches siding track segment occupied by LW
Scenario Steps	1. LW observes train approaching. 2. TO blows whistle. 3. LW clears track to PPOS. 4. TO proceeds on mainline past siding track segment.
End State (Happy Path)	1. LW cleared track. 2. Train proceeded.

6.1.5 Lone Worker – Double Track

ID	UC-RWP-105
Title	Lone Worker – Double Track
Description	Lone worker must foul track Main 1 to perform inspection or minor adjustment/repair; train on track Main 2 approaches work area
Method of Operation	Any
RR Personnel	LW, TO
RR Systems	Transit Train
Reference Track Configuration	Double track per section 4.1.5.
Initial Condition	1. LW determines maximum train speed. 2. LW determines clear time and predetermined place of safety. 3. LW determines sight distance available. 4. LW determines sight distance required using speed/sight distance table. 5. Track Main 1 to be accessed by LW is unoccupied. 6. LW accesses track Main 1 and begins work if ITD is adequate.
Trigger Event	Train on track Main 2 approaches track segment occupied by LW

Scenario Steps	1. LW observes Train approaching. 2. TO blows whistle. 3. LW clears track Main 1 to PPOS. 4. TO proceeds through track Main 2 segment.
End State (Happy Path)	1. LW cleared track to PPOS clear of all tracks. 2. Train proceeded.

6.1.6 Lone Worker – Double Track with Single Crossovers

ID: UC-RWP-106
Reference Track Configuration: Double Track with Single Crossovers per section 4.1.6.

- Handle in accordance with use case 6.1.4.

6.1.7 Lone Worker – Double Track with Universal Crossovers

ID: UC-RWP-107
Reference Track Configuration: Double Track with Universal Crossovers per section 4.1.7.

- Handle in accordance with use case 6.1.4.

6.2 Watchman/Lookout Use Cases

The Watchman/Lookout (WL) use case set (UC-RWP-200) describes how one or more WLs provide protection for a group of RWs who do not have exclusive track occupancy authority from a dispatcher. Under Watchman/Lookout method of on-track protection, one or more watchmen are responsible for spotting approaching trains and warning roadway workers with enough time to clear from the track. Requirements of Watchman/Lookout Protection (WLP) are the following:

- WLs are trained and qualified to perform their tasks.
- WLs must have sight distance in all directions along the tracks to provide a minimum warning time to RW equal to the time required for RW to safely clear the track, plus at least 15 seconds.
- WLs must have effective means to communicate with RWs.
- WLs must be positioned at a location where their ability to detect approaching trains in a timely manner is not impaired by background noise, lights, precipitation, fog, passing trains, or any other physical conditions.
- WLs sole responsibility is to watch for trains and provide warning to RWs while not engaging in any other duties.
- WLs must remain in the clear of all tracks while performing their duties, unless necessary for the proper performance of those duties.
- RW are performing work that is of a “non-complex nature” and will not disrupt the track structure or substructure.

Table C-4 provides a list of use cases in this series.

Table C-4 *Watchman/Lookout (WL) Use Cases*

Use Case ID	Use Case Title
UC-RWP-201	Watchman/Lookout – Single Track
UC-RWP-202	Watchman/Lookout – Single Track with Uncontrolled Spur Track
UC-RWP-203	Watchman/Lookout – Single Track with Diverging Mainline
UC-RWP-204	Watchman/Lookout – Single Track with Siding
UC-RWP-205	Watchman/Lookout – Double Track
UC-RWP-206	Watchman/Lookout – Double Track with Single Crossovers
UC-RWP-207	Watchman/Lookout – Double Track with Universal Crossovers
UC-RWP-208	Watchman/Lookout – Triple Track
UC-RWP-209	Watchman/Lookout – Quad Track

6.2.1 Watchman/Lookout – Single Track

ID	UC-RWP-201
Title	Watchmen/Lookout Protection – Single Track
Description	RW(s) under same WLP must foul main track to perform adjustments and/or repairs; train on main track approaches work area
Method of Operation	Any
RR Personnel	EIC, WL(s), RW(s), TO
RR Systems	Transit train
Reference Track Configuration	Single track per section 4.1.1.
Initial Condition	1. EIC determines maximum train speed approaching work area. 2. EIC determine sight distance available. 3. EIC determine sight distance required using speed/ sight distance table. 4. WL(s) obtain clear time estimate from EIC. 5. EIC briefs WL(s) and RW(s) on conditions (i.e., train speed, clear-to location(s), etc.) 6. WL(s) to get in appropriate position to watch for trains and to alert RW(s) of approaching trains. 7. Main track to be accessed by RW(s) is unoccupied by train or other vehicles. 8. RW(s) access track and begin work.
Trigger Event	Train approaches track segment occupied by RW(s)
Scenario Steps	1. WL(s) observes Train approaching. 2. TO observes RW(s) and blows whistle. 3. WL(s) alerts RW(s) of approaching train. 4. RW(s) clear track to PPOS, to include any tools that may be in the foul. 5. Train proceeds through track segment.
End State (Happy Path)	1. WL(s) and RW(s) cleared all tracks. 2. Train proceeds.

6.2.2 Watchman/Lookout – Single Track with Uncontrolled Spur Track

ID	UC-RWP-202
Title	Watchman/Lookout Protection – Single Track with Uncontrolled Spur Track
Description	RW(s) under same WLP must foul main track to perform adjustments and/or repairs; train on spur track approaches work area
Method of Operation	Any
RR Personnel	EIC, WL(s), RW(s), TO
RR Systems	Transit Train
Reference Track Configuration	Single track with uncontrolled spur per section 4.1.2.
Initial Condition	1. EIC determines maximum train speed for approaches to work area, including spur track. 2. EIC determine sight distance available. 3. EIC determine sight distance required using speed/ sight distance table. 4. WL(s) obtain clear time estimate from EIC. 5. EIC briefs WL(s) and RW(s) on conditions (i.e., train speed, clear-to location(s), etc.) 6. WL(s) to get in appropriate position to watch for trains and alert RW(s) of approaching train. 7. Main track to be accessed by RW(s) is unoccupied by train or other vehicles. 8. RW(s) access Main track and begin work.
Trigger Event	Train on spur track approaches track segment occupied by RW(s)
Scenario Steps	1. WL(s) observes train approaching on spur track. 2. TO observes RW(s) and blows whistle. 3. WL(s) alerts RW(s) of approaching train. 4. RW(s) clear track to PPOS, to include any tools that may be in the foul. 5. TO proceeds through track segment.
End State (Happy Path)	WL(s) and RW(s) cleared all tracks. Train proceeds.

6.2.3 Watchman/Lookout – Single Track with Diverging Mainline

ID	UC-RWP-203
Title	Watchman/Lookout Protection – Single Track with Diverging Mainline
Description	RW(s) under same WLP must foul east-west main track to perform adjustments and/or repairs; train on north-south main track approaches work area.
Method of Operation	Any
RR Personnel	EIC, WL(s), RW(s), TO
RR Systems	Transit Train
Reference Track Configuration	Single track with diverging mainlines per section 4.1.3.
Initial Condition	1. EIC determines maximum train speed for approaches to work area, including diverging mainline. 2. EIC determine sight distance available. 3. EIC determine sight distance required using speed/sight distance table. 4. WL(s) obtain clear time estimate from EIC. 5. EIC briefs WL(s) RW(s) on conditions (i.e., train speed, clear-to location(s), etc.) 6. WL(s) to get in appropriate position to watch for trains and alert RW(s) of approaching train. 7. Track segment to be accessed by RW(s) is unoccupied by train or other vehicles. 8. RW(s) access east-west main track and begin work.

Trigger Event	Train on north-south main approaches track segment occupied by RW(s)
Scenario Steps	1. WL(s) observes train approaching. 2. TO observes RW(s) and blows whistle. 3. WL(s) alerts RW(s) of approaching train. 4. RW (s) clear track to PPOS, to include any tools that may be in the foul. 5. TO proceeds on East-West Main.
End State (Happy Path)	1. WL(s) and RW(s) cleared all tracks. 2. Train proceeds.

6.2.4 Watchman/Lookout – Single Track with Siding

ID	UC-RWP-204
Title	Watchman/Lookout Protection – Single Track with Siding
Description	RW(s) under same WLP must access siding to perform adjustments and/or repairs; train on main track approaches work area.
Method of Operation	Any
RR Personnel	EIC, WL(s), RW(s), TO
RR Systems	Transit Train
Reference Track Configuration	Single track with siding per section 4.1.4.
Initial Condition	1. EIC determines maximum train speed approaching work area. 2. EIC determine sight distance available. 3. EIC determine sight distance required using speed/sight distance table. 4. WL(s) obtain clear time estimate, to include any tools that may be in the foul from EIC. 5. EIC briefs RW(s) on conditions (i.e., train speed, clear-to location(s), etc.) 6. WL(s) to get in appropriate position to watch for Trains and alert RW(s) of approaching Train. 7. Siding track segment to be accessed by RW(s) is unoccupied by train or other on-track vehicles. 8. RW(s) access siding track and begin work.
Trigger Event	Train on main track approaches siding track segment occupied by RW(s)
Scenario Steps	1. Train approaches track segment occupied by RW(s). 2. WL(s) observes train approaching. 3. TO observes RW(s) and blows whistle. 4. WL(s) alerts RW(s) of approaching Train. 5. RW(s) clear track to PPOS, to include any tools that may be in the foul. 6. Train on Main track proceeds past siding track segment.
End State (Happy Path)	1. WL(s) and RW(s) cleared all tracks. 2. Train proceeds.

6.2.5 Watchman/Lookout – Double Track

ID	UC-RWP-205
Title	Watchman/Lookout Protection – Double Track
Description	RW(s) under same WLP must foul track Main 1 to perform adjustments and/or repairs; train on track Main 2 approaches work area
Method of Operation	Any

RR Personnel	EIC, WL, RW(s), TO
RR Systems	Transit Train
Reference Track Configuration	Double track per section 4.1.5
Initial Condition	1. EIC determines maximum train speed approaching work area. 2. EIC determine sight distance available. 3. EIC determine sight distance required using speed/sight distance table. 4. WL(s) obtain clear time estimate to include any tools that may be in the foul from EIC. 5. EIC briefs WL(s) and RW(s) on conditions (i.e., train speed, clear-to location(s), etc.) 6. WL(s) to get in appropriate position to watch for trains and alert RW(s) of approaching trains. 7. Track Main 1 to be accessed by RW(s) is unoccupied by train. 8. RW(s) access track Main 1 and begin work.
Trigger Event	Train on track Main 2 approaches track segment adjacent to track Main 1 occupied by RW(s)
Scenario Steps	1. WL(s) observes train approaching. 2. TO observes RW(s) and blows whistle. 3. WL(s) alerts RW(s) of approaching trains. 4. RW(s) clear track to PPOS, to include any tools that may be in the foul. 5. Train on track Main 2 proceeds past track Main 1 track segment.
End State (Happy Path)	1. WL(s) and RW(s) cleared all tracks. 2. Train proceeds.

6.2.6 Watchman/Lookout – Double Track with Single Crossovers

ID: UC-RWP-206
Reference Track Configuration: Double Track with Single Crossovers per section 4.1.6.

- Handle in accordance with use case 6.2.5.

6.2.7 Watchman/Lookout – Double Track with Universal Crossovers

ID: UC-RWP-207
Reference Track Configuration: Double Track with Universal Crossovers per section 4.1.7.

- Handle in accordance with use case 6.2.5.

6.3 Acquisition of Authority to Access Track Use Cases

The Acquisition of Authority to Access Track (UC-RWP-300) use case set describes the processes and communication exchange by which a TO or EIC of a work group obtains exclusive occupancy of a track from a dispatcher or by a track bulletin. Acquisition of exclusive authority cases do not describe how RWs are protected on track; rather, they are referenced by the UC-RWP-400 and UC-RWP-500 series use case initial conditions. Table C-5 provides a list of use cases in this series.

Table C-5 *Acquisition of Exclusive Authority Use Cases*

Use Case ID	Use Case Title
UC-RWP-301	Acquisition of Exclusive Occupancy Authority Track Warrant Territory
UC-RWP-302	Acquisition of Exclusive Occupancy in Centralized Traffic Control
UC-RWP-303	Acquisition of Exclusive Occupancy in Territory Governed by Block System Rules
UC-RWP-304	Acquisition of Joint Occupancy Track Warrant
UC-RWP-305	Acquisition of Joint/Overlapping Track and Time
UC-RWP-306	Acquisition of Joint/Overlapping Authority Track Permit
UC-RWP-307	Accessing Track Under Exclusive Occupancy Authority Held by Another Employee
UC-RWP-308	Acquisition of Track Bulletin Protection

6.3.1 Acquisition of Exclusive Occupancy Authority in TWC Territory

ID	UC-RWP-301
Title	Acquisition of Exclusive Occupancy Authority Track Warrant Territory
Description	EIC or TO, requests from Dispatcher, an EOA (TW) to access track TWC territory
Method of Operation	TWC
RR Personnel	EIC (or TO), Dispatcher
RR Systems	DBO
Reference Track Configuration	Any
Initial Condition	1. Main track(s) between WKL_A and WKL_B (track segment AB) to be accessed by RW gang is unoccupied. 2. No other existing EOA has been granted to others for requested track(s) segment AB for the requested time.
Trigger Event	EIC (or TO) contacts Dispatcher to request access to Main track between points A and B.
Scenario Steps	1. Dispatcher verifies, via DBO, track segment AB has no effective TW. 2. Dispatcher creates TW request via DBO. 3. Dispatcher reads TW to EIC (or TO). 4. EIC (or TO) copies TW. 5. EIC (or TO) reads back TW to Dispatcher. 6. Dispatcher verifies TW and gives OK time to EIC (or TO).
End State (Happy Path)	EOA in effect providing EIC (or TO) authority to access Main track between WKL_A and WKL_B, protecting them from other train movements.

6.3.2 Acquisition of Exclusive Occupancy in CTC Territory (Track and Time)

Authority to occupy interlocking limits must be separately obtained, under the rules for the specific interlocking.

ID	UC-RWP-302
Title	Acquisition of Exclusive Occupancy in CTC (Track and Time)
Description	EIC or TO, requests from Dispatcher, an exclusive track occupancy (Track and Time) to access track in CTC territory

Method of Operation	CTC
RR Personnel	EIC (or TO), Dispatcher
RR Systems	DBO
Reference Track Configuration	Any
Initial Condition	1. Main track between CP WKL_A and CP WKL_B (track segment AB) to be accessed by RW gang is unoccupied at the requested time. 2. No other existing EOA has been granted to others for requested track(s) segment AB for the requested time.
Trigger Event	EIC (or TO) contacts Dispatcher to request access to Main track(s) between CP A and CP B.
Scenario Steps	1. Dispatcher verifies, via DBO, track segment AB has no effective EOA for requested time. 2. Dispatcher creates Track and Time and applies blocking of Main track(s) at CP WKL_A and CP WKL_B via DBO. 3. Dispatcher reads Track and Time to EIC (or TO). 4. EIC (or TO) copies Track and Time. 5. EIC (or TO) reads back Track and Time to Dispatcher. 6. Dispatcher verifies Track and Time and acknowledges accuracy to EIC (or TO).
End State (Happy Path)	EOA in effect providing EIC (or TO) authority to access Main track between WKL_A and WKL_B, protecting them from other train movements.

6.3.3 Acquisition of Exclusive Occupancy in Territory Governed by Block System Rules (Track Permit)

Note: Track Permit limits, designated by a switch, extend only to the signal governing movement over the switch, unless otherwise designated.

Note: The primary difference between Track Permit and Track and Time is:

- Track Permit is effective immediately upon completion of issuing process.
- Track and Time has defined start time that may or may not be the time of completion of issuance, and end time.

ID	UC-RWP-303
Title	Acquisition of Exclusive Occupancy in Territory Governed by Block System Rules (Track Permit)
Description	EIC or TO, requests from Dispatcher, an exclusive track occupancy (Track Permit) to access track in Block System Rules governed territory.
Method of Operation	Block System Rules
RR Personnel	EIC (or TO), Dispatcher
RR Systems	DBO
Reference Track Configuration	Any
Initial Condition	1. Main track between CP WKL_A and CP WKL_B (track segment AB) to be accessed by RW gang is unoccupied. 2. No other EOA for requested track(s) over segment AB established.
Trigger Event	EIC (or TO) contacts Dispatcher to request access to main track(s) between CP A and CP B.

Scenario Steps	1. Dispatcher verifies, via DBO, track segment AB has no effective EOA for requested time. 2. Dispatcher creates Track Permit and applies blocking of main track(s) at CP WKL$_A$ and CP WKL$_B$ via DBO. 3. Dispatcher reads Track Permit to EIC (or TO). 4. EIC (or TO) copies Track Permit. 5. EIC (or TO) reads back Track Permit to Dispatcher. 6. Dispatcher verifies Track Permit and acknowledges accuracy to EIC (or TO).
End State (Happy Path)	EOA in effect providing EIC (or TO) authority to access Main track between WKL$_A$ and WKL$_B$, protecting them from other train movements.

6.3.4 Acquisition of Joint/Overlapping Occupancy Track Warrant

ID	UC-RWP-304
Title	Acquisition of Joint/Overlapping Occupancy Track Warrant
Description	EIC or TO, requests from Dispatcher, a track warrant to access track segment which overlaps TW issued to a train, vehicle, or other employees.
Method of Operation	Any
RR Personnel	EIC (or TO), Dispatcher
RR Systems	DBO
Reference Track Configuration	Any
Initial Condition	1. Main track between WKL$_A$ and WKL$_B$ (track segment AB) to be accessed by RW gang is occupied by other trains, vehicles, or employees. 2. TW(s) providing authority to (another) train to occupy track segment AB already established.
Trigger Event	EIC (or TO) contacts Dispatcher to request access to main track between points A and B.
Scenario Steps	1. Dispatcher identifies, via DBO, existing unidirectional TW for a train overlapping track segment AB. 2. Dispatcher informs EIC (or TO) of overlapping limits with train's TW (men/equipment not to occupy track ahead of train). 3. Dispatcher creates TW request via DBO (including information on joint TW). 4. Dispatcher reads TW to EIC (or TO), noting that other trains, vehicles, or employees are occupying track. 5. Dispatcher informs other TW holders that other trains, vehicles, or employees are occupying track. 6. EIC (or TO) copies TW. 7. EIC (or TO) reads back TW to Dispatcher. 8. Dispatcher verifies TW and gives OK time to EIC (or TO).
End State (Happy Path)	Joint TW in effect providing EIC (or TO) authority to access Main track between WKL$_A$ and WKL$_B$, protecting them from other train movements.

6.3.5 Acquisition of Joint/Overlapping Track and Time

Note: Track and Time does not authorize occupancy of track(s) within interlocking limits.

ID	UC-RWP-305
Title	Acquisition of Joint/Overlapping Track and Time
Description	EIC or TO, requests from Dispatcher, a track occupancy authority (Track and Time) to access track in CTC territory which overlaps authority issued to a train, vehicle, or other employees.

Method of Operation	CTC
RR Personnel	EIC (or TO), Dispatcher
RR Systems	DBO
Reference Track Configuration	Any
Initial Condition	1. Main track between CP WKL_A and CP WKL_B (track segment AB) to be accessed by RW gang is unoccupied at the requested time. 2. Track and Time or Track Permit providing authority to (other) train, vehicles, or employees to occupy track segment AB already established.
Trigger Event	EIC (or TO) contacts Dispatcher to request access to Main track between CP A and CP B.
Scenario Steps	1. Dispatcher verifies, via DBO, track segment AB has no effective EOA for requested time. 2. Dispatcher creates Track and Time and applies blocking of Main track(s) at CP WKL_A and CP WKL_B via DBO. 3. Dispatcher reads Track and Time to EIC (or TO), noting that other trains, vehicles, or employees are occupying track. 4. Dispatcher informs other track occupancy authority holders that other trains, vehicles, or employees are occupying track. 5. EIC (or TO) copies Track and Time. 6. EIC (or TO) reads back Track and Time to Dispatcher. 7. Dispatcher verifies Track and Time and acknowledges accuracy to EIC (or TO).
End State (Happy Path)	Joint Track and Time authority effect providing EIC (or TO) authority to access Main track between WKL_A and WKL_B, protecting them from other train movements.

6.3.6 Acquisition of Joint/Overlapping Authority Track Permit

Note: Track Permit limits, designated by a switch, extend only to the signal governing movement over the switch, unless otherwise designated.

Note: The primary difference between Track Permit and Track and Time is:

- Track Permit is effective immediately upon completion of issuing process.
- Track and Time has defined start time that may or may not be the time of completion of issuance, and end time.

ID	UC-RWP-306
Title	Acquisition of Joint/Overlapping Authority Track Permit
Description	EIC or TO, requests from Dispatcher, track occupancy (Track Permit) to access track in Block System Rules governed territory that is occupied by another train, vehicle, or other employees.
Method of Operation	Block System Rules
RR Personnel	EIC (or TO), Dispatcher
RR Systems	DBO
Reference Track Configuration	Any
Initial Condition	1. Main track between CP WKL_A and CP WKL_B (track segment AB) to be accessed by RW gang is occupied by other trains, vehicles, or employees occupying track. 2. No other existing EOA has been granted to others for requested track(s) segment AB for the requested time.

Trigger Event	EIC (or TO) contacts Dispatcher to request access to Main track(s) between CP A and CP B.
Scenario Steps	1. Dispatcher verifies, via DBO, track segment AB has no effective EOA for requested time. 2. Dispatcher creates Track Permit and applies blocking of Main track(s) at CP WKL_A and CP WKL_B via DBO. 3. Dispatcher reads Track Permit to EIC (or TO); noting that other trains, vehicles, or employees are occupying track. 4. Dispatcher informs other track permit holders that other trains, vehicles, or employees are occupying track. 5. EIC (or TO) copies Track Permit. 6. EIC (or TO) reads back Track Permit to Dispatcher. 7. Dispatcher verifies Track Permit and acknowledges accuracy to EIC (or TO).
End State (Happy Path)	Track Permit in effect providing EIC (or TO) authority to access Main track between WKL_A and WKL_B, protecting them from other train movements.

6.3.7 Accessing Track Under Exclusive Occupancy Authority Held by Another Employee

ID	UC-RWP-307
Title	Accessing Track Under Exclusive Occupancy Authority Held by Another Employee
Description	EIC-1 of primary work gang, or TO, requests from Dispatcher, an EOA (TW) to access track TWC territory per UC-RWP-301 or UC-RWP-302 as appropriate.
Method of Operation	TWC, CTC
RR Personnel	EIC-1 (or TO-1), EIC-2 (or TO-2)
RR Systems	None
Reference Track Configuration	Any
Initial Condition	1. Main track(s) between WKL_A and WKL_B (track segment AB) to be accessed by secondary RW gang is unoccupied. 2. Portion of track to be accessed by secondary RW gang is away from portion of track occupied by primary RW gang.
Trigger Event	EIC-2 (or TO-2) contacts EIC-1 (or TO-1) and requests JO under established TW.
Scenario Steps	1. EIC-1 (or TO-1) reads TW to EIC-2 (or TO-2). 2. EIC-2 (or TO-2) copies TW. 3. EIC-2 (or TO-2) reads back TW to EIC-1 (or TO-1). 4. EIC-1 (or TO-1) verifies TW and gives OK time to EIC-2 (or TO-2).
End State (Happy Path)	EOA in effect providing EIC-2 (or TO-2) authority to access Main track between WKL_A and WKL_B, protecting them from other train movements.

6.3.8 Acquisition of Track Bulletin Protection

ID	UC-RWP-308
Title	Acquisition of Track Bulletin Protection
Description	Track bulletin defining work zone is established in advance of EIC of work gang accessing track to perform work tasks.
Method of Operation	Any

RR Personnel	EIC (or TO), for foreman/manager of RW, Dispatcher
RR Systems	DBO (or bulletin system)
Reference Track Configuration	Any
Initial Condition	EIC or manager of RWs, 24 hours or more (per RR operating practices) prior to scheduled work, enters bulletin data into RR bulletin system defining date, time, subdivision, EIC, location of work (Main track between WKL_A and WKL_B (track segment AB), etc.
Trigger Event	Start of day track bulletin is effective.
Scenario Steps	1. Track bulletin distributed to all trains that will operate on subdivision in which track bulletin is effective. 2. TO of each train receives track bulletin at initial station, or from prior TO. 3. TO members compare copies of track bulletin to verify. 4. TO contacts Dispatcher and verifies track bulletin prior to entry to subdivision.
End State (Happy Path)	Track bulletin in effect providing EIC authority to access Main track between WKL_A and WKL_B, protecting them from other train movements.

6.4 Train Coordination Use Cases

The train coordination use case set (UC-RWP-400) describes how a TO, who has exclusive occupancy authority over a segment of track, cedes control of that authority to an EIC who manages on-track protection through coordination of the activities of RWs and the train.

Under train coordination method of on-track protection, working limits are established within a segment of track(s) upon which only one train holds exclusive authority to move. Requirements of train coordination are as follows:

- Train is visible to EIC establishing work limits.
- Train is initially stopped when Train Coordination is established.
- Movement of train within work limits will only be made by train under the instruction of EIC while work limits remain in effect.
- TO will not release exclusive authority to move until the work limits have been released by EIC.

Table C-6 provides a list of use cases in this series.

Table C-6 *Train Coordination Use Cases*

Use Case ID	Use Case Title
UC-RWP-401	Train Coordination – Single Track
UC-RWP-402	Train Coordination – Single Track with Uncontrolled Spur Track
UC-RWP-403	Train Coordination – Single Track with Diverging Mainline
UC-RWP-404	Train Coordination – Single Track with siding
UC-RWP-405	Train Coordination – Double Track
UC-RWP-406	Train Coordination – Double Track with Single Crossovers

Use Case ID	Use Case Title
UC-RWP-407	Train Coordination – Double Track with Universal Crossovers
UC-RWP-408	Train Coordination – Triple Track
UC-RWP-409	Train Coordination – Quad Track

6.4.1 Train Coordination – Single Track

ID	UC-RWP-401
Title	Train Coordination – Single Track
Description	Train Coordination used to provide protection to RW(s) accessing main track.
Method of Operation	Train Coordination
RR Personnel	Dispatcher, TO, EIC, RW
RR Systems	Dispatch, Work Train, Transit Train
Reference Track Configuration	Single track per section 4.1.1.
Initial Condition	1. TO of Work Train obtains exclusive occupancy TW on main track between WKL_A and WKL_B per use case 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 2. TO of Work Train reads TW to EIC. 3. EIC copies TW. 4. EIC reads back TW to TO of Work Train. 5. TO of Work Train verifies TW. 6. TO of Work Train cedes control to EIC. 7. RW(s) access Main track, as defined in TW
Trigger Event	Train approaches end of MA at WKL_A on Main track.
Scenario Steps	1. Transit train approaches end of MA at WKL_A. 2. TO of transit train contacts Dispatcher and requests TW (MA) to proceed beyond WKL_A on Main track. 3. Dispatcher denies TW to TO of transit train; exclusive occupancy TW for Main track segment AB is in effect. 4. TO stops transit train short of WKL_A on Main track. 5. Upon completion of work, RWs clear themselves and equipment from Main track. 6. EIC verifies RW(s) and equipment are clear of Main track. 7. EIC contacts TO of Work Train. 8. EIC cedes control of TW back to Work Train TO. 9. TO of Work Train contacts Dispatcher to request TW to proceed beyond WKL_B on Main track per use case 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 10. Work train clears WKL_B on Main track. 11. TO of Work Train contacts Dispatcher and releases TW for segment AB of Main track. 12. Dispatcher clears Work Train's TW for Main track segment AB via DBO. 13. Dispatcher creates TW for Transit train that includes all or part of track segment AB via DBO. 14. Dispatcher contacts TO of transit train and provides TW information. 15. Dispatcher verifies receipt of TW by TO of transit train.
End State (Happy Path)	1. RW(s) are clear of Main track segment AB. 2. Transit train proceeds into Main track segment AB.

6.4.2 Train Coordination – Single Track with Uncontrolled Spur Track

ID	UC-RWP-402
Title	Train Coordination – Single Track with Uncontrolled Spur Track
Description	Train Coordination used to provide protection to RW(s) accessing Main track. Uncontrolled spur track intersects Main track within limits of exclusive occupancy authority held by Train. Train approaches on spur track.
Method of Operation	Train Coordination
RR Personnel	Dispatcher, TO, EIC, RW
RR Systems	Dispatch, Train
Reference Track Configuration	Single track with uncontrolled spur per section 4.1.2.
Initial Condition	1. TO of Work Train obtains exclusive occupancy TW on Main track between WKL_A and WKL_B per use case 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 2. TO of Work Train reads TW to EIC. 3. EIC copies TW 4. EIC reads back TW to TO of Work Train. 5. TO of Work Train verifies TW. 6. TO of Work Train cedes control to EIC. 7. RW(s) access Main track as defined in TW.
Trigger Event	Train on spur track approaches junction of mainline.
Scenario Steps	1. Transit train approaches end of MA at junction. 2. TO of transit train contacts Dispatcher and requests TW (MA) to proceed past junction to mainline. 3. Dispatcher denies TW to TO of transit train, exclusive occupancy TW for Main track segment AB in effect. 4. TO stops Transit train short of junction to mainline. 5. Upon completion of work, RW(s) clear themselves and equipment from Main track. 6. EIC verifies workers and equipment are in the clear of Main track. 7. EIC contacts TO of Work Train to cedes control of TW back to Work Train TO. 8. TO of Work Train contacts Dispatcher to request TW to proceed beyond WKLB per use case 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 9. Work Train clears of WKL_B on Main track 10. Dispatcher clears Work Train's TW for Main track segment AB via DBO. 11. Dispatcher contacts TO of transit train and provides TW information. 12. Dispatcher verifies receipt of TW by TO of transit train.
End State (Happy Path)	1. Work train and RW(s) are clear of Main track segment AB. 2. Transit train proceeds into Main track segment AB.

6.4.3 Train Coordination – Single Track with Diverging Mainline

ID	UC-RWP-403
Title	Train Coordination – Single Track with Diverging Mainline
Description	Train coordination used to provide protection to RW(s) accessing East-West Main track. Diverging North-South Main track intersects East-West Main track within limits of exclusive occupancy authority held by Work Train. Train approaches on diverging North-South Main track.
Method of Operation	Train Coordination

RR Personnel	Dispatcher, TO, EIC, RW
RR Systems	Dispatch, Transit Train
Reference Track Configuration	Single track with diverging mainlines per section 4.1.3.
Initial Condition	1. TO of Work Train obtains exclusive occupancy TW on East-West Main track between WKL_A and WKL_B per use case 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 2. TO of Work Train reads TW to EIC. 3. EIC copies TW. 4. EIC reads back TW to TO of Work Train. 5. TO of Work Train verifies TW. 6. TO of Work Train cedes control to EIC. 7. RW(s) access East-West Main track, as defined in TW.
Trigger Event	Train on North-South Main approaches junction of mainline occupied by RW(s).
Scenario Steps	1. Transit train approaches MA at junction. 2. TO of transit train contacts Dispatcher and requests TW (MA) to proceed past junction to East-West mainline. 3. Dispatcher denies TW to TO of transit train; exclusive occupancy TW for East-West Main track segment AB in effect. 4. TO stops transit train short of junction mainline. 5. Upon completion of work, RW(s) clear themselves and equipment from East-West Main track. 6. EIC verifies workers and equipment are in the clear of East-West Main track. 7. EIC contacts TO of Work Train to cedes control of TW back to Work Train TO. 8. TO of Work Train contacts Dispatcher to request TW to proceed beyond WKL_B per use case 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 9. When Work Train is clear of WKL_B on East-West Main track, TO of Work Train contacts Dispatcher and releases TW for segment AB of East-West Main track. 10. Dispatcher clears Work Train's TW for East-West Main track segment AB via DBO. 11. Dispatcher contacts TO of Transit Train and provides TW information. 12. Dispatcher verifies receipt of TW by TO of Transit Train.
End State (Happy Path)	1. Work Train RW(s) are clear of East-West Main track segment AB. 2. Transit Train proceeds into East-West Main track segment AB.

6.4.4 Train Coordination – Single Track with Siding

ID: UC-RWP-404

Reference Track Configuration: Single Track with Siding per section 4.1.4.

- Handle in accordance with use case 6.4.1

6.4.5 Train Coordination – Double Track (Exclusive Occupancy on Track Main 1 and Track Main 2)

ID	UC-RWP-405
Title	Train Coordination – Double Track
Description	Train Coordination used to provide protection to RW(s) accessing track Main 1. Transit Train on track Main 2 approaches work area.
Method of Operation	Train Coordination
RR Personnel	Dispatcher, TO, EIC, RW

RR Systems	Dispatch, Work Train, Transit Train
Reference Track Configuration	Double track per section 4.1.5.
Initial Condition	1. TO of Work Train obtains exclusive occupancy TW on track Main 1 and track Main 2 between WKL_A and WKL_B per use case 7.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 2. TO of Work Train reads TW to EIC. 3. EIC copies TW. 4. EIC reads back TW to TO of Work Train. 5. TO of Work Train verifies TW. 6. TO of Work Train cedes control to EIC. • RW(s) access tracks between WKL_A and WKL_B, as defined in TW.
Trigger Event	Transit Train on track Main 2 approaches track segment occupied by RW(s).
Scenario Steps	Handle in accordance with uses case 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory.
End State (Happy Path)	1. Work Train and RW(s) are clear of track Main 1. 2. Transit Train can proceed on Track Main 2.

6.4.6 Train Coordination – Double Track with Single Crossovers

ID: UC-RWP-406
Reference Track Configuration: Double Track with Single Crossovers per section 4.1.6.

- Handle in accordance with use case 6.4.5

6.4.7 Train Coordination – Double Track with Universal Crossovers

ID: UC-RWP-407
Reference Track Configuration: Double Track with Universal Crossovers per section 4.1.7.

- Handle in accordance with use case 6.4.5

6.5 Exclusive Track Occupancy – Track Warrant Control Use Cases

The exclusive track occupancy use case set (UC-RWP-500) describes the processes by which a RW, or a RW gang, establishes and maintains on-track safety and interacts with trains operating near, or within, work limits defined by an exclusive track occupancy authority track warrant control. If PTC is available, then PTC system components enforce train MA limits and provide TO information as denoted in scenario steps. Table C-7 provides a list of use cases in this series.

Table C-7 *Exclusive Track Occupancy – Track Warrant Control Use Cases*

Use Case ID	Use Case Title
UC-RWP-501	Exclusive Track Occupancy – TWC – Single Track
UC-RWP-502	Exclusive Track Occupancy – TWC – Single Track with Uncontrolled Spur Track
UC-RWP-503	Exclusive Track Occupancy – TWC – Single Track with Diverging Mainline
UC-RWP-504	Exclusive Track Occupancy – TWC – Single Track with Siding
UC-RWP-505	Exclusive Track Occupancy – TWC – Double Track
UC-RWP-506	Exclusive Track Occupancy – TWC – Double Track with Single Crossovers
UC-RWP-507	Exclusive Track Occupancy – TWC – Double Track with Universal Crossovers
UC-RWP-508	Exclusive Track Occupancy – TWC – Triple Track
UC-RWP-509	Exclusive Track Occupancy – TWC – Quad Track

6.5.1 Exclusive Track Occupancy – TWC – Single Track

ID	UC-RWP-501
Title	Exclusive Track Occupancy – TWC – Single Track
Description	Exclusive occupancy authority used to provide protection to RW(s) accessing Main track. Train on Main track approaches work area.
Method of Operation	TWC
RR Personnel	EIC, RW, Dispatcher, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Single Track per section 4.1.1.
Initial Condition	1. EIC of RW(s) obtains exclusive authority TW on Main track between WKL_A and WKL_B per use case 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 2. EIC or designee displays flags at work limits as defined by applicable operating rules. 3. RW(s) access Main track, as defined in TW.
Trigger Event	Train approaches end of MA at WKL_A on Main track.
Scenario Steps	1. Train approaches end of MA at WKL_A on Main track. 2. TO of Train contacts Dispatcher and requests TW to proceed beyond WKL_A. 3. Dispatcher verifies, via DBO, TW is in effect for track segment AB. 4. Dispatcher denies TW to TO – exclusive occupancy TW in effect. 5. TO stops Train short of WKL_A. 6. RW(s) access Main track within track segment AB until work is complete. 7. Upon completion of work, RW(s) clear themselves and equipment from track. 8. EIC verifies all worker(s) clear of track segment AB. 9. EIC contacts Dispatcher and releases TW for track segment AB. 10. Dispatcher clears EIC's TW for track segment AB via DBO. 11. Dispatcher creates TW for Train that includes all or part of track segment AB via DBO. 12. Dispatcher contacts TO of Train and provides TW information. 13. Dispatcher verifies receipt of TW by TO of Train.
End State (Happy Path)	1. RW(s) are clear of Main track segment AB. 2. Train proceeds into Main track segment AB.

6.5.2 Exclusive Track Occupancy – TWC – Single Track with Uncontrolled Spur Track

ID	UC-RWP-502
Title	Exclusive Track Occupancy – TWC – Single Track with Uncontrolled Spur Track
Description	Exclusive occupancy authority used to provide protection to RW(s) accessing Main track. Uncontrolled spur track intersects Main track within limits of exclusive occupancy authority held by EIC of RW(s). Train approaches on spur track.
Method of Operation	TWC
RR Personnel	EIC, RW, Dispatcher, Train Crew
RR Systems	DBO, Transit Train,
Reference Track Configuration	Single track with uncontrolled spur per section 4.1.2.
Initial Condition	1. EIC of RW(s) obtains exclusive authority TW on Main track between WKL_A and WKL_B per use case 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 2. EIC or designee displays flags at work limits as defined by applicable operating rules. 3. RW(s) access Main track, as defined in TW.
Trigger Event	Train on spur track approaches junction of mainline.
Scenario Steps	1. Train on spur approaches junction to mainline. 2. TO of Train contacts Dispatcher and requests TW (MA) to proceed past junction to mainline. 3. Dispatcher denies TW to TO of Train, exclusive occupancy TW for Main track segment AB in effect. 4. TO stops Train short of junction at mainline. 5. Upon completion of work, RW(s) clear themselves and equipment from track. 6. EIC verifies workers and equipment are in the clear of track. 7. EIC contacts Dispatcher and releases TW for segment AB of Main track. 8. Dispatcher clears EIC's TW for Main track segment AB via DBO. 9. Dispatcher contacts TO and provides TW information. 10. Dispatcher verifies receipt of TW by TO.
End State (Happy Path)	1. RW(s) are clear of Main track segment AB. 2. Train proceeds onto Main track segment AB.

6.5.3 Exclusive Track Occupancy – TWC – Single Track with Diverging Mainline

ID	UC-RWP-503
Title	Exclusive Occupancy – TWC – Single Track with Diverging Mainline
Description	Exclusive occupancy authority used to provide protection to RW(s) accessing East-West Main track. Diverging North-South Main track intersects East-West Main track within limits of exclusive occupancy authority held by EIC of RW(s). Train approaches on diverging North-South Main track.
Method of Operation	TWC
RR Personnel	EIC, RW, Dispatcher, Train Crew
RR Systems	DBO, Transit Train,
Reference Track Configuration	Single track with diverging mainlines per section 4.1.3.

Initial Condition	1. EIC of RW(s) obtains exclusive authority TW on East-West Main track between WKL_A and WKL_B per use case 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 2. EIC or designee displays flags at work limits as defined by applicable operating rules. 3. RW(s) access East-West Main track, as defined in TW.
Trigger Event	Train on North-South Main track approaches junction of mainline occupied by RW(s).
Scenario Steps	1. Train on North-South Main train approaches junction of mainline occupied by RW(s). 2. TO of Train contacts Dispatcher and requests TW (MA) to proceed past junction to mainline. 3. Dispatcher denies TW to TO; exclusive occupancy TW for East-West Main track segment AB in effect. 4. TO stops Train short of junction at mainline. 5. Upon completion of work, RW(s) clear themselves and equipment from East-West Main track. 6. EIC verifies RW(s) and equipment are in the clear of East-West Main track. 7. EIC contacts Dispatcher and releases TW for segment AB of East-West Main track. 8. Dispatcher clears EIC's TW for East-West Main track segment AB via DBO. 9. Dispatcher contacts TO of Train and provides TW information. 10. Dispatcher verifies receipt of TW by TO.
End State (Happy Path)	1. RW(s) are clear of East-West Main track segment AB. 2. Train proceeds onto East-West Main track segment AB.

6.5.4 Exclusive Track Occupancy – TWC – Single Track with Siding

ID: UC-RWP-504

Reference Track Configuration: Single Track with Siding per section 4.1.4.

- Handle in accordance with use case 6.5.3

6.5.5 Exclusive Track Occupancy – TWC – Double Track (Exclusive Occupancy on Track Main 1 and Track Main 2)

ID	UC-RWP-505a
Title	Exclusive Track Occupancy – TWC – Double Track
Description	Exclusive Occupancy – TWC used to provide protection to RW(s) accessing track Main 1. Train on track Main 2 approaches work area.
Method of Operation	TWC
RR Personnel	EIC, RW (s), Dispatcher, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Double track per section 4.1.5.
Initial Condition	1. EIC of RW(s) obtains exclusive occupancy TW on track Main 1 and track Main 2 between WKL_A and WKL_B per 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 2. EIC or designee displays flags at work limits as defined by applicable operating rules. 3. RW(s) access tracks between WKL_A and WKL_B, as defined in TW.
Trigger Event	Train on track Main 2 approaches track segment occupied by RW(s).
Scenario Steps	Handle in accordance with use case 4.1.5
End State (Happy Path)	1. RW(s) are clear of authority. 2. Train can proceed.

6.5.6 Exclusive Track Occupancy – TWC – Double Track (Exclusive Occupancy on Track Main 1, Watchman/Lookout on Track Main 2)

ID	UC-RWP-505b
Title	Exclusive Track Occupancy – TWC – Double Track
Description	Exclusive Occupancy – TWC used to provide protection to RW(s) accessing track Main 1. Train on track Main 2 approaches work area.
Method of Operation	TWC
RR Personnel	EIC, WM, RW, Dispatcher, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Double track per section 4.1.5.
Initial Condition	1. EIC of RW(s) obtains exclusive occupancy TW on track Main 1 between WKL_A and WKL_B per 6.3.1. Acquisition of Exclusive Occupancy Authority in TWC Territory. 2. EIC or designee displays flags at work limits as defined by applicable operating rules. 3. EIC designates WKL on track Main 2 per use case 6.2.5. Watchman/Lookout – Double Track. 4. RW(s) access track Main 1, as defined in TW.
Trigger Event	Train on track Main 2 approaches track segment adjacent to track Main 1 occupied by RW(s). Train on track Main 2 has TW to proceed past work area.
Scenario Steps	1. WM observes Train approaching on track Main 2. 2. TO observes RW(s) on track Main 1 and blows whistle. 3. WM alerts RW(s) of approaching Train on track Main 2. 4. RW(s) clear from foul of track Main 2 and area between tracks Main 1 and Main 2, to include any tools and equipment, which may be in use. *Note: RW(s) may remain within the gauge of track Main 1.* 5. Train on track Main 2 proceeds past Main 1 track segment WKL_A WKL_B.
End State (Happy Path)	1. Train proceeds past work area on track Main 2. 2. RW(s) continue work on track Main 1.

6.5.7 Exclusive Track Occupancy – TWC – Double Track with Single Crossovers

ID: UC-RWP-506
Reference Track Configuration: Double Track with Single Crossovers per section 4.1.6.

- Handle in accordance with use case 6.5.5

6.5.8 Exclusive Track Occupancy – TWC – Double Track with Universal Crossovers

ID: UC-RWP-507
Reference Track Configuration: Double Track with Universal Crossovers per section 4.1.7.

- Handle in accordance with use case 6.5.5

6.6 Exclusive Track Occupancy – Centralized Traffic Control Use Cases

The exclusive track occupancy use case (UC-RWP-600) describes the processes by which a Roadway Worker, or a gang of Roadway Workers, establishes and maintains on-track safety and interacts with trains operating near, or within, work limits defined by an exclusive track occupancy authority track warrant control. If PTC is available, then PTC system components enforce train MA limits and provide TO information as denoted in scenario steps.

Table C-8 provides a list of use cases in this series.

Table C-8 *Exclusive Track Occupancy – Centralized Traffic Control Use Cases*

Use Case ID	Use Case Title
UC-RWP-601	Exclusive Track Occupancy – CTC – Single Track
UC-RWP-602	Exclusive Occupancy – CTC – Single Track with Uncontrolled Spur Track
UC-RWP-603	Exclusive Track Occupancy – CTC – Single Track with Diverging Mainline
UC-RWP-604	Exclusive Track Occupancy – CTC – Single Track with Siding
UC-RWP-605	Exclusive Track Occupancy – CTC – Double Track
UC-RWP-606	Exclusive Track Occupancy – CTC – Double Track with Single Crossovers
UC-RWP-607	Exclusive Track Occupancy – CTC – Double Track with Universal Crossovers
UC-RWP-608	Exclusive Track Occupancy – CTC – Triple Track
UC-RWP-609	Exclusive Track Occupancy – CTC – Quad Track

6.6.1 Exclusive Track Occupancy – CTC – Single Track

ID	UC-RWP-601
Title	Exclusive Track Occupancy – CTC – Single Track
Description	Exclusive occupancy authority used to provide protection to RW(s) accessing Main track. Train on Main track approaches work area.
Method of Operation	CTC
RR Personnel	EIC, RW(s), Dispatcher, Train Crew
RR Systems	DBO, Transit Train,
Reference Track Configuration	Single Track per section 4.1.1.
Initial Condition	1. EIC of RW(s) obtains exclusive authority TW on Main track between WKL_A and WKL_B per use case 6.3.2. Acquisition of Exclusive Occupancy in CTC Territory (Track and Time). 2. RW(s) access Main track, as defined in TW.
Trigger Event	Train approaches end of MA at WKL_A on Main track.

Scenario Steps	1. Train approaches end of MA at WKL_A on Main track. 2. TO of Train contacts Dispatcher and requests TW to proceed beyond WKL_A. 3. Dispatcher verifies, via DBO, TW is in effect for track segment AB. 4. Dispatcher denies TW to TO – exclusive occupancy TW in effect. 5. TO stops Train short of WKL_A. 6. RW(s) access Main track within track segment AB until work is complete. 7. Upon completion of work, RW(s) clear themselves and equipment from Main track. 8. EIC verifies all RW(s) clear of track segment AB. 9. EIC contacts Dispatcher and releases TW for track segment AB. 10. Dispatcher clears EIC's TW for track segment AB via DBO. 11. Dispatcher creates TW for Train that includes all or part of track segment AB via DBO. 12. Dispatcher contacts TO of Train and provides TW information. 13. Dispatcher verifies receipt of TW by TO.
End State (Happy Path)	1. RW(s) are clear of Main track segment AB. 2. Train proceeds into Main track segment AB.

6.6.2 Exclusive Track Occupancy – CTC – Single Track with Uncontrolled Spur Single Track

ID	UC-RWP-602
Title	Exclusive Track Occupancy – CTC – Single Track with Uncontrolled Spur Track
Description	Exclusive occupancy authority used to provide protection to RW(s) accessing Main track. Uncontrolled spur track intersects Main track within limits of exclusive occupancy authority held by EIC of RW(s). Train approaches on spur track.
Method of Operation	CTC
RR Personnel	EIC, RW, Dispatcher, Train Crew
RR Systems	DBO, Train,
Reference Track Configuration	Single track with uncontrolled spur per section 4.1.2.
Initial Condition	1. EIC of RW(s) obtains exclusive authority TW on Main track between WKL_A and WKL_B per 6.3.2. Acquisition of Exclusive Occupancy in CTC Territory (Track and Time). 2. RW(s) access Main track, as defined in TW.
Trigger Event	Train on spur track approaches junction of mainline.
Scenario Steps	1. Train approaches MA at junction to mainline. 2. TO of Train contacts Dispatcher and requests TW (MA) to proceed past junction to mainline. 3. Dispatcher denies TW to TO of Train, exclusive occupancy TW for Main track segment AB in effect. 4. TO stops Train short of junction at mainline. 5. Upon completion of work, RW(s) clear themselves and equipment from track. 6. EIC verifies RW(s) and equipment are in the clear of track. 7. EIC contacts Dispatcher and releases TW for segment AB of Main track. 8. Dispatcher clears EIC's TW for Main track segment AB via DBO. 9. Dispatcher contacts TO of Train and provides TW information. 10. Dispatcher verifies receipt of TW by TO.
End State (Happy Path)	1. RW(s) are clear of Main track segment AB. 2. Train proceeds onto Main track segment AB.

6.6.3 Exclusive Track Occupancy – CTC – Single Track with Diverging Mainline

ID	UC-RWP-603
Title	Exclusive Occupancy – CTC – Single Track with Diverging Mainline
Description	Exclusive occupancy authority used to provide protection to RW(s) accessing East-West Main track. Diverging North-South Main track intersects East-West Main track within limits of exclusive occupancy authority held by EIC of RW(s). Train approaches on diverging North-South Main track.
Method of Operation	CTC
RR Personnel	EIC, RW, Dispatcher, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Single track with diverging mainlines per section 4.1.3.
Initial Condition	1. EIC of RW(s) obtains exclusive authority TW on East-West Main track between WKL_A and WKL_B per use case 6.3.2. Acquisition of Exclusive Occupancy in CTC Territory (Track and Time). 2. RW(s) access East-West Main track, as defined in TW.
Trigger Event	Train on North-South Main track approaches junction of mainline occupied by RW(s).
Scenario Steps	1. Train on North-South Main track approaches junction of mainline occupied by RW(s). 2. TO of Train contacts Dispatcher and requests TW (MA) to proceed past junction to mainline. 3. Dispatcher denies TW to TO of Train; exclusive occupancy TW for East-West Main track segment AB in effect. 4. TO stops Train short of junction at mainline. 5. Upon completion of work, RW(s) clear themselves and equipment from East-West Main track. 6. EIC verifies RW(s) and equipment are in the clear of East-West Main track. 7. EIC contacts Dispatcher and releases TW for segment AB of East-West Main track. 8. Dispatcher clears EIC's TW for East-West Main track segment AB via DBO. 9. Dispatcher contacts TO of Train and provides TW information. 10. Dispatcher verifies receipt of TW by TO.
End State (Happy Path)	1. RW(s) are clear of East-West Main track segment AB. 2. Train proceeds onto East-West Main track segment AB.

6.6.4 Exclusive Track Occupancy – CTC – Single Track with Siding

ID: UC-RWP-604

Reference Track Configuration: Single Track with Siding per section 4.1.4.

- Handle in accordance with use case 6.6.1

6.6.5 Exclusive Track Occupancy – CTC – Double Track (Exclusive Occupancy on Track Main 1 and Track Main 2)

ID	UC-RWP-605a
Title	Exclusive Track Occupancy – CTC – Double Track
Description	Exclusive Occupancy – TWC used to provide protection to RW(s) accessing track Main 1. Train on track Main 2 approaches work area.
Method of Operation	TWC

RR Personnel	EIC, RW, Dispatcher, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Double track per section 4.1.5.
Initial Condition	1. EIC of RW(s) obtains exclusive occupancy TW on track Main 1 and track Main 2 between WKL_A and WKL_B per 6.3.2. Acquisition of Exclusive Occupancy in CTC Territory (Track and Time). 2. RW(s) access tracks between WKL_A and WKL_B, as defined in TW.
Trigger Event	Train on track Main 2 approaches track segment occupied by RW(s).
Scenario Steps	Handle in accordance with use case 6.3.2. Acquisition of Exclusive Occupancy in CTC Territory (Track and Time)
End State (Happy Path)	1. RW(s) are clear of authority. 2. Train can proceed.

6.6.6 Exclusive Track Occupancy – CTC – Double Track (Exclusive Occupancy on Track Main 1, Watchman/Lookout on Track Main 2)

ID	UC-RWP-605b
Title	Exclusive Track Occupancy – CTC – Double Track
Description	Exclusive Occupancy – CTC used to provide protection to RW(s) accessing track Main 1. Train on track Main 2 approaches work area.
Method of Operation	TWC
RR Personnel	EIC, WM, RW, Dispatcher, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Double track per section 4.1.5.
Initial Condition	1. EIC of RW(s) obtains exclusive occupancy TW on track Main 1 between WKL_A and WKL_B per user case 6.3.2. 2. EIC designates WKL on track Main 2 per use case 6.2.5. Watchman/Lookout – Double Track. 3. RW(s) access track Main 1, as defined in TW.
Trigger Event	Train on track Main 2 approaches track segment adjacent to track Main 1 occupied by RW(s). Train on track Main 2 has TW to proceed past work area.
Scenario Steps	1. WM observes Train approaching on track Main 2. 2. TO observes RW(s) on track Main 1 and blows whistle. 3. WM alerts RW(s) of approaching Train on track Main 2. 4. RW(s) clear from foul of track Main 2 and area between tracks Main 1 and Main 2, to include any tools and equipment, that may be in use. *Note: RW(s) may remain within the gauge of track Main 1.* 5. Train on track Main 2 proceeds past Main 1 track segment WKL_A WKL_B.
End State (Happy Path)	1. RW(s) continue work on track Main 1. 2. Train proceeds past work area on track Main 2.

6.6.7 Exclusive Track Occupancy – CTC – Double Track with Single Crossovers

ID: UC-RWP-606
Reference Track Configuration: Double Track with Single Crossovers per section 4.1.6.

- Handle in accordance with use case 6.6.5

6.6.8 Exclusive Track Occupancy – CTC – Double Track with Universal Crossovers

ID: UC-RWP-607
Reference Track Configuration: Double Track with Universal Crossovers per section 4.1.7.

- Handle in accordance with use case 6.6.5

6.7 Track Bulletin Use Cases

The track bulletin use case set (UC-RWP-700) describes the processes by which a Roadway Worker, or a gang of Roadway workers, establishes and maintains on-track safety and interacts with trains operating near, or within, work limits defined by a track bulletin. If PTC is available, then PTC system components enforce train MA limits and provide TO information as denoted in scenario steps.

Table C-9 provides a list of use cases in this series.

Table C-9 *Track Bulletin Use Cases*

Use Case ID	Use Case Title
UC-RWP-701	Track Bulletin – Single Track
UC-RWP-702	Track Bulletin – Single Track with Uncontrolled Spur Track
UC-RWP-703	Track Bulletin – Single Track with Diverging Mainline
UC-RWP-704	Track Bulletin – Single Track with Siding
UC-RWP-705	Track Bulletin – Double Track
UC-RWP-706	Track Bulletin – Double Track with Single Crossovers
UC-RWP-707	Track Bulletin – Double Track with Universal Crossovers
UC-RWP-708	Track Bulletin – Triple Track
UC-RWP-709	Track Bulletin – Quad Track

6.7.1 Track Bulletin – Single Track

ID	UC-RWP-701
Title	Track Bulletin – Single Track
Description	Track bulletin used to provide protection to RW(s) accessing Main track.
Method of Operation	TB
RR Personnel	EIC, RW, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Single Track per section 4.1.1.
Initial Condition	1. EIC of RW(s) obtains TB on Main track between WKL_A and WKL_B per use case 6.3.8. 2. RW(s) access Main track, as defined in TB.
Trigger Event	Train approaches end of MA at WKL_A on Main track.
Scenario Steps	1. TB provided to TO of Train at initial station unless otherwise instructed by Dispatcher. 2. Train approaches end of MA at WKL_A. 3. TO of Train contacts EIC and requests permission to proceed beyond WKL_A. 4. TO stops Train short of WKL_A. 5. EIC denies TO permission past WKL_A. 6. RW(s) access Main track within track segment AB until work is complete. 7. Upon completion of work, RW(s) clear themselves and equipment from Main track. 8. EIC verifies all RW(s) are clear of track segment AB. 9. EIC contacts TO of Train and grants permission to proceed beyond WKL_A through work zone at a given speed.
End State (Happy Path)	1. RW(s) are clear of Main track segment AB. 2. Train proceeds into Main track segment AB.

6.7.2 Track Bulletin – Single Track with Uncontrolled Spur Track

ID	UC-RWP-702
Title	Track Bulletin – Single Track with Uncontrolled Spur Track
Description	Track bulletin used to provide protection to RW(s) accessing Main track. Uncontrolled spur track intersects Main track within limits of track bulletin. Train approaches on spur track.
Method of Operation	TB
RR Personnel	EIC, RW(s), Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Single Track with Uncontrolled Spur Track per section 4.1.2.
Initial Condition	1. EIC of RW(s) obtains TB on Main track between WKL_A and WKL_B per use case 6.3.8. 2. RW(s) access Main track, as defined in TB.
Trigger Event	Train approaches junction to mainline on uncontrolled spur track.

Scenario Steps	1. TB provided to TO at initial station unless otherwise instructed by Dispatcher. 2. Train approaches end of MA at junction to mainline. 3. TO contacts EIC and requests permission to proceed past junction to mainline. 4. TO stops short of junction to mainline. 5. EIC denies TO permission past junction to mainline. 6. RW(s) access Main track within track segment AB until work is complete. 7. Upon completion of work, RW(s) clear themselves and equipment from Main track. 8. EIC verifies all RW(s) are clear of track segment AB. 9. EIC contacts TO and grants permission to proceed beyond junction to mainline, through work zone, at a given speed.
End State (Happy Path)	1. RW(s) are clear of Main track segment AB. 2. Train proceeds onto Main track segment AB.

6.7.3 Track Bulletin – Single Track with Diverging Mainline

ID	UC-RWP-703
Title	Track Bulletin – Single Track with Diverging Mainline
Description	Track bulletin used to provide protection to RW(s) accessing East-West Main track. Diverging North-South Main track intersects East-West Main track within limits of track bulletin. Train approaches on diverging North-South Main track.
Method of Operation	TB
RR Personnel	EIC, RW, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Single Track with Uncontrolled Spur Track per section 4.1.2.
Initial Condition	1. EIC of RW(s) obtains TB on East-West Main track between WKL_A and WKL_B per use case 6.3.8. 2. RW(s) access East-West Main track, as defined in TB.
Trigger Event	Train on North-South Main track approaches junction of mainline occupied by RW(s).
Scenario Steps	1. TB provided to TO of Train at initial station unless otherwise instructed by Dispatcher. 2. Train approaches end of MA at junction to mainline. 3. TO of Train contacts EIC and requests permission to proceed past junction to mainline. 4. TO stops Train short of junction to mainline. 5. EIC denies TO of Train permission past junction to mainline. 6. RW(s) access East-West Main track within track segment AB until work is complete. 7. Upon completion of work, RW(s) clear themselves and equipment from East-West Main track. 8. EIC verifies all RW(s) are clear of East-West Main track segment AB. 9. EIC contacts TO of Train and grants permission to proceed beyond junction to mainline, through work zone, at a given speed.
End State (Happy Path)	1. RW(s) are clear of East-West Main track segment AB. 2. Train proceeds onto East-West Main track segment AB.

6.7.4 Track Bulletin – Single Track with Siding

ID: UC-RWP-704

Reference Track Configuration: Single Track with Siding per section 4.1.4.

- Handle in accordance with use case 6.7.1

6.7.5 Track Bulletin – Double Track (Track Bulletin establishing Work Limits on Track Main 1 and Track Main 2)

ID	UC-RWP-705a
Title	Track Bulletin – Double Track
Description	Track bulletin used to provide protection to RW(s) accessing Main track. Train on track Main 2 approaches work area.
Method of Operation	TB
RR Personnel	EIC, RW, Dispatcher, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Double track per section 4.1.5.
Initial Condition	1. EIC of RW(s) obtains TB on tracks Main 1 and Main 2 between WKL_A and WKL_B per use case 6.3.8. 2. RW(s) access tracks between WKL_A and WKL_B, as defined in TW.
Trigger Event	Train on track Main 2 approaches track segment occupied by RW(s).
Scenario Steps	Handle in accordance with use case 6.3.8. Acquisition of Track Bulletin Protection
End State (Happy Path)	1. RW(s) are clear of authority. 2. Train can proceed.

6.7.6 Track Bulletin – Double Track (Track Bulletin establishing Work Limits on Track Main 1, Watchman/Lookout on Track Main 2)

ID	UC-RWP-705b
Title	Track Bulletin – Double Track
Description	Track bulletin used to provide protection to RW(s) accessing Main track. Train on track Main 2 approaches work area.
Method of Operation	TB
RR Personnel	EIC, WM, RW, Dispatcher, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Double track per section 4.1.5.
Initial Condition	1. EIC of RW(s) obtains TB on track Main 1 between WKL_A and WKL_B per use case 6.3.8. 2. EIC designates WKL on track Main 2 per use case 6.2.5. Watchman/Lookout – Double Track. 3. RW(s) access track Main 1, as defined in TB.
Trigger Event	Train on track Main 2 approaches track segment adjacent to track Main 1 occupied by RW(s). Train on track Main 2 has TW to proceed past work area.
Scenario Steps	1. WM observes Train approaching on track Main 2. 2. TO observes RW(s) on track Main 1 and blows whistle. 3. WM alerts RW(s) of approaching Train on track Main 2. 4. RW(s) clear from foul of track Main 2 and area between tracks Main 1 and Main 2, to include any tools and equipment, which may be in use. *Note: RW(s) may remain within the gauge of track Main 1.* 5. Train on track Main 2 proceeds past Main 1 track segment WKL_A WKL_B.
End State (Happy Path)	1. RW(s) continue work on track Main 1. 2. Train proceeds past work area on track Main 2.

6.7.7 Track Bulletin – Double Track with Single Crossovers

ID: UC-RWP-706
Reference Track Configuration: Double Track with Single Crossovers per section 4.1.6.

- Handle in accordance with use case 6.7.6

6.7.8 Track Bulletin – Double Track with Universal Crossovers

ID: UC-RWP-707
Reference Track Configuration: Double Track with Universal Crossovers per section 4.1.7.

- Handle in accordance with use case 6.7.6

6.8 Joint Occupancy Use Cases

The joint occupancy use case set (UC-JOP-800) describes the processes by which a separate work group is afforded on-track safety by the EIC of a pre-established exclusive track occupancy, and that is located away from the EIC of the pre-established exclusive track occupancy. If PTC is available, then PTC system components enforce train MA limits and provide TO information as denoted in scenario steps.

Table C-10 *Joint Occupancy Use Cases*

Use Case ID	Use Case Title
UC-JOP-801	Joint Occupancy – Single Track
UC-JOP-802	Joint Occupancy – Single Track with Uncontrolled Spur Track
UC-JOP-803	Joint Occupancy – Single Track with Diverging Mainline
UC-JOP-804	Joint Occupancy – Single Track with Siding
UC-JOP-805	Joint Occupancy – Double Track
UC-JOP-806	Joint Occupancy – Double Track with Single Crossovers
UC-JOP-807	Joint Occupancy – Double Track with Universal Crossovers
UC-JOP-808	Joint Occupancy – Triple Track
UC-JOP-809	Joint Occupancy – Quad Track

6.8.1 Joint Occupancy – Single Track

ID	UC-JOP-801
Title	Joint Occupancy – Single Track
Description	Joint Occupancy of exclusive occupancy authority used to provide protection to a second group of RW(s) accessing Main track.
Method of Operation	CTC, TWC
RR Personnel	EIC-1, EIC-2, RW, Train Crew

RR Systems	DBO, Transit Train
Reference Track Configuration	Single Track per section 4.1.1.
Initial Condition	1. EIC-1 of RW(s) obtains exclusive authority TW on Main track between WKL_A and WKL_B per use case 6.3.4. Acquisition of Joint/Overlapping Occupancy Track Warrant. 2. RW(s) access Main track, as defined in TW. 3. EIC-2 of second RW(s) contacts EIC-1 to obtain joint occupancy TW per use case 6.3.7. Accessing Track Under Exclusive Occupancy Authority Held by Another Employee. 4. RW(s) in second work group access track WKL_A and WKL_B, as defined in TW.
Trigger Event	Train approaches end of MA at WKL_A on Main track.
Scenario Steps	1. Train approaches end of MA at WKL_A. 2. TO of Train contacts Dispatcher and requests TW to proceed beyond WKL_A. 3. Dispatcher verifies, via DBO, TW is in effect for track segment AB. 4. Dispatcher denies TW to TO of Train – exclusive occupancy TW in effect. 5. TO stops Train short of WKL_A. 6. RW(s) access Main track within track segment AB until work is complete. 7. Upon completion of work, RW(s) clear themselves and equipment from Main track. 8. EIC-1 verifies all RW(s) clear of track segment AB. 9. EIC-1 contacts EIC-2 to verify all RW(s) are clear of track segment AB. 10. EIC-2 confirms RW(s) are clear of track segment AB. 11. EIC-2 releases JO. 12. EIC-1 contacts Dispatcher and releases TW for track segment AB. 13. Dispatcher clears EIC-1's TW for track segment AB via DBO. 14. Dispatcher creates TW for Train that includes all or part of track segment AB via DBO. 15. Dispatcher contacts TO of Train and provides TW information. 16. Dispatcher verifies receipt of TW by TO.
End State (Happy Path)	1. All RW(s) are clear of Main track segment AB. 2. Train proceeds into Main track segment AB.

6.8.2 Joint Occupancy – Single Track with Uncontrolled Spur Track

ID	UC-JOP-802
Title	Joint Occupancy – Single Track with Uncontrolled Spur Track
Description	Joint Occupancy of exclusive occupancy authority used to provide protection to a second group of RW(s) accessing Main track. Uncontrolled spur track intersects Main track within limits of track bulletin. Train approaches on spur track.
Method of Operation	CTC, TWC
RR Personnel	EIC-1, EIC-2, RW, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Single Track with Uncontrolled Spur Track per section 4.1.2.
Initial Condition	1. EIC-1 of RW(s) obtains exclusive authority TW on Main track between WKL_A and WKL_B per use case 6.3.4. Acquisition of Joint/Overlapping Occupancy Track Warrant. 2. RW(s) access Main track, as defined in TW. 3. EIC-2 of second RW(s) contacts EIC-1 to obtain joint occupancy TW per use case 6.3.7. Accessing Track Under Exclusive Occupancy Authority Held by Another Employee. 4. RW(s) in second work group access track WKL_A and WKL_B, as defined in TW.
Trigger Event	Train approaches junction to mainline on uncontrolled spur track.

Scenario Steps	1. Train approaches end of MA at WKL_A to TO. 2. TO of Train contacts Dispatcher and requests TW to proceed beyond WKL_A. 3. Dispatcher verifies, via DBO, TW is in effect for track segment AB. 4. Dispatcher denies TW to TO – exclusive occupancy TW in effect. 5. TO stops Train short of WKL_A. 6. RW(s) access Main track within track segment AB until work is complete. 7. Upon completion of work, RW(s) clear themselves and equipment from Main track. 8. EIC-1 verifies all RW(s) clear of track segment AB. 9. EIC-1 contacts EIC-2 to verify all RW(s) are clear of track segment AB. 10. EIC-2 confirms RW(s) are clear of track segment AB. 11. EIC-2 releases JO. 12. EIC-1 contacts Dispatcher and releases TW for track segment AB. 13. Dispatcher clears EIC-1's TW for track segment AB via DBO. 14. Dispatcher creates TW for Train that includes all or part of track segment AB via DBO. 15. Dispatcher contacts TO of Train and provides TW information. 16. Dispatcher verifies receipt of TW by TO.
End State (Happy Path)	1. All RW(s) are clear of Main track segment AB. 2. Train proceeds into Main track segment AB.

6.8.3 Joint Occupancy – Single Track with Diverging Mainline

ID	UC-JOP-803
Title	Joint Occupancy – Single Track with Diverging Mainline
Description	Joint Occupancy of exclusive occupancy authority used to provide protection to a second group of RW(s) accessing East-West Main track. Diverging North-South Main track intersects East-West Main track within limits of track bulletin. Train approaches on diverging North-South Main track.
Method of Operation	CTC, TWC
RR Personnel	EIC-1, EIC-2, RW, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Single Track with Diverging Mainline per section 4.1.3.
Initial Condition	1. EIC-1 of RW(s) obtains exclusive authority TW on East-West Main track between WKL_A and WKL_B per use case 6.3.4. Acquisition of Joint/Overlapping Occupancy Track Warrant. 2. RW(s) access East-West Main track, as defined in TW. 3. EIC-2 of second RW(s) contacts EIC-1 to obtain joint occupancy TW per use case 6.3.7. Accessing Track Under Exclusive Occupancy Authority Held by Another Employee. 4. RW(s) in second work group access East-West Main track WKL_A and WKL_B, as defined in TW.
Trigger Event	Train approaches junction to mainline on diverging mainline.

Scenario Steps	1. Train approaches end of MA at WKL_A. 2. TO of Train contacts Dispatcher and requests TW to proceed beyond WKL_A. 3. Dispatcher verifies, via DBO, TW is in effect for track segment AB. 4. Dispatcher denies TW to TO – exclusive occupancy TW in effect. 5. TO stops Train short of WKL_A. 6. RW(s) access East-West Main track within track segment AB until work is complete. 7. Upon completion of work, RW(s) clear themselves and equipment from East-West Main track. 8. EIC-1 verifies all RW(s) clear of track segment AB. 9. EIC-1 contacts EIC-2 to verify all RW(s) are clear of track segment AB. 10. EIC-2 confirms RW(s) are clear of track segment AB. 11. EIC-2 releases JO. 12. EIC-1 contacts Dispatcher and releases TW for track segment AB. 13. Dispatcher clears EIC-1's TW for track segment AB via DBO. 14. Dispatcher creates TW for Train that includes all or part of track segment AB via DBO. 15. Dispatcher contacts TO of train and provides TW information. 16. Dispatcher verifies receipt of TW by TO.
End State (Happy Path)	1. All RW(s) are clear of East-West Main track segment AB. 2. Train proceeds into East-West Main track segment AB.

6.8.4 Joint Occupancy – Single Track with Siding

ID: UC-RWP-804

Reference Track Configuration: Single Track with Siding per section 4.1.4.

- Handle in accordance with use case 6.8.1

6.8.5 Joint Occupancy – Double Track (Exclusive Occupancy on Track Main 1 and Track Main 2)

ID	UC-JOP-805a
Title	Joint Occupancy – Double Track
Description	Joint Occupancy of exclusive occupancy authority used to provide protection to a second group of RW(s) accessing Main track. Train on track Main 2 approaches work area.
Method of Operation	CTC, TWC
RR Personnel	EIC-1, EIC-2, RW, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Double track per section 4.1.5.
Initial Condition	1. EIC-1 of RW(s) obtains exclusive occupancy TW on track Main 1 and track Main 2 between WKL_A and WKL_B per use case 6.3.4. Acquisition of Joint/Overlapping Occupancy Track Warrant. 2. RW(s) access tracks between WKL_A and WKL_B, as defined in TW. 3. EIC-2 of second RW(s) contacts EIC-1 to obtain joint occupancy TW per use case 6.3.7. Accessing Track Under Exclusive Occupancy Authority Held by Another Employee. 4. RW(s) in second work group access tracks WKL_A and WKL_B, as defined in TW.
Trigger Event	Train on track Main 2 approaches track segment occupied by RW(s).
Scenario Steps	Handle in accordance with use case 6.3.4. Acquisition of Joint/Overlapping Occupancy Track Warrant.

End State (Happy Path)	1. RW(s) are clear of authority. 2. Train can proceed.

6.8.6 Joint Occupancy – Double Track (Exclusive Occupancy on Track Main 1, Watchman/Lookout on Track Main 2)

ID	UC-JOP-805b
Title	Joint Occupancy – Double Track
Description	Joint Occupancy of exclusive occupancy authority used to provide protection to a second group of RW(s) accessing Main track. Train on track Main 2 approaches work area.
Method of Operation	CTC, TWC
RR Personnel	EIC-1, EIC-2, RW, Train Crew
RR Systems	DBO, Transit Train
Reference Track Configuration	Double track per section 4.1.5.
Initial Condition	1. EIC of RW(s) obtains exclusive occupancy TW on track Main 1 between WKL_A and WKL_B per use case 6.3.4. Acquisition of Joint/Overlapping Occupancy Track Warrant. 2. EIC designates WKL on track Main 2 per use case 6.2.5. Watchman/Lookout – Double Track. 3. RW(s) access track Main 1, as defined in TW. 4. EIC-2 of second RW(s) contacts EIC-1 to obtain joint occupancy TW per use case 6.3.7. Accessing Track Under Exclusive Occupancy Authority Held by Another Employee. 5. EIC-2 designates WKL on track Main 2 per use case 6.2.5. Watchman/Lookout – Double Track 6. RW(s) in second work group access tracks WKL_A and WKL_B, as defined in TW.
Trigger Event	Train on track Main 2 approaches track segment adjacent to track Main 1 occupied by RW(s). Train on track Main 2 has TW to proceed past work area.
Scenario Steps	1. WM, from both work groups, observes Train approaching on track Main 2. 2. TO of Train observes RW(s) on track Main 1 and blows whistle. 3. WM, from both work groups, alerts RW(s) of approaching Train on track Main 2. 4. RW(s), from both work groups, clear from foul of track Main 2 and area between tracks Main 1 and Main 2, to include any tools and equipment, that may be in use. Note: RW(s) may remain within the gauge of track Main 1. 5. Train on track Main 2 proceeds past Main 1 track segment WKL_A WKL_B.
End State (Happy Path)	1. RW(s) continue work on track Main 1. 2. Train proceeds past work area on track Main 2.

6.8.7 Joint Occupancy – Double Track with Single Crossovers

ID: UC-RWP-806

Reference Track Configuration: Double Track with Single Crossovers per section 4.1.6.

- Handle in accordance with use case 6.8.5

6.8.8 Joint Occupancy – Double Track with Universal Crossovers

ID: UC-RWP-807
Reference Track Configuration: Double Track with Universal Crossovers per section 4.1.7.

- Handle in accordance with use case 6.8.5

Appendix D

Concept of Operation (CONOPS) for an RWP Safety System

Introduction

Development and implementation of an RWP safety system can reduce the risk of roadway worker injuries when engaged in activities within the right-of-way of track. This appendix summarizes the current methods of roadway worker protection and explains how an RWP safety system can be used in conjunction with current practices to improve overall safety for the roadway worker.

An RWP safety system is not necessarily a single system; rather, it is a suite of risk-reducing system concepts intended to improve worker safety by reducing specific risks through enhancing situational awareness of roadway workers. Such a system can add an enhanced layer of safety in addition to RWP safety rules and procedures. The user platform for this risk reduction concept is a small portable device that can be worn by a roadway worker, watchman, and/or employee-in-charge (EIC). A cell phone or tablet may have the capability to perform the intended functions of such a concept; however, to reduce the risk of distraction by other functions, the device needs to be dedicated to RWP. The device should have the capability to be used in different modes specific to the risk reduction concept being used and should be able to alert the roadway worker, watchman, and EIC via a visual, audible, and physical alert.

Roadway workers are trained in operating rules and procedures before being allowed to establish on-track protection. However, hazardous events can still occur due to human error. An RWP safety system is intended as an additional measure of safety to work in conjunction with current operating rules to aid in mitigating accidents caused by human error on the part of the roadway worker.

RWP Use Cases and Scenarios

Transit rail roadway workers currently follow operating rules to ensure safety when working within the foul limits of any track, bridge, or wayside structure. These rules are intended to ensure the safety of roadway workers and should be strictly adhered to while performing any work function within the designated track foul limits.

Workers are trained on various forms of on-track protection and the proper establishment of those forms of protection before performing job functions within the foul of track. Track foul limits are established by each transit agency. The methods of on-track protection used by roadway workers described in this document include:

- Lone Worker
- Watchman/Lookout
- Train Coordination
- Exclusive Authority
- Track Bulletin
- Joint Occupancy

These processes are described in greater detail in Appendix C, “RWP Use Cases.”

Transit Rail Personnel Involved in RWP

A designated group of transit rail personnel is involved in setting up and maintaining RWP while performing job functions:

- **Roadway Worker** (Lone Worker or as part of team) is the person responsible for performing the work on the track or other rail structure located on or within the foul limits of track. The job functions of a roadway worker can vary from simple visual track inspections to entire removal and replacement of track structure, subgrade, or bridges. A roadway worker can perform specific functions alone as a Lone Worker or as part of a team of workers, often referred to as a roadway workgroup.
- **Watchman/Lookout** is responsible for serving as the lookout for personnel performing a job function requiring them to foul track. The watchman has one responsibility—watching for oncoming rail traffic or hazards. They must stay within such proximity to the roadway worker such that they can signal the worker of hazards and/or oncoming rail traffic. The signal to clear track may be visual, audible, physical, or any combination of the three. The proper method of presenting a signal to clear the track is dependent on the job function being performed. For example, when a roadway worker is using loud power tools such as a rail grinder, the watchman must be close enough to use a physical signal (e.g., touching the worker on the shoulder) to alert the workmen.
- **Employee In Charge (EIC)** is the member of the worker team who is responsible for coordinating track time, working limits, and communications with dispatcher and other railroad entities as required. The EIC is also the leader of the team performing work that requires them to foul track. A Lone Worker assumes the role as EIC when working alone.
- **Dispatcher/Rail Traffic Controller (RTC)** supervises train movement and any employees connected with that movement. They are also responsible for train dispatch and coordination of track bulletins around train movements. The EIC and the dispatcher communicate to set up work zones when using Exclusive Track Occupancy and Track Warrant as a method of roadway worker safe work zones.

- **Train Crew (Engineer and Conductor)** are the railroad personnel responsible for operations of a road train or work train. A roadway worker may be required to communicate directly with the train crew if Train Coordination is used as the RWP safety method. Under all other safety methods, communication with the train crew is normally directly with the dispatcher.

Current Roadway Worker Protection Methods

Lone Worker Protection

A Lone Worker is an individual roadway worker who has been annually trained and qualified but is not afforded on-track protection by another roadway worker, is not a member of a roadway work group, and is not engaged in a common task with another roadway worker. A Lone Worker is responsible for their own safety while on track or within the foul of track. They must be able to see approaching trains with enough advance warning to be clear of the track 15 seconds[39] before a train's arrival. See Appendix C for more detail.

Watchman/Lookout

Watchman/Lookout is a method of establishing on track protection via an employee who has been annually trained and qualified to provide warning to roadway workers of approaching trains or on-track equipment. Watchman/Lookouts should be properly equipped to provide visual and auditory warnings such as a whistle, air horn, white disk, red flag, lantern, or fuse. A Watchman/Lookout's sole duty is to look out for approaching trains/on-track equipment and provide adequate time for workmen to be positioned in the clear of the track no less than 15 seconds before the arrival of trains/on-track equipment. See Appendix C for more detail.

Train Coordination

Train Coordination is a method of establishing working limits on a track over which a train holds exclusive authority to move whereby the crew of that train yields that authority to the roadway worker. Train Coordination provides for personnel or equipment to use a train's authority to establish working limits. An employee must contact the train's engineer to request use of Train Coordination. To establish working limits:

- The train must be in view and stopped, with controls set and centered.
- The employee in charge of working limits will communicate with the engineer who will notify other crew members that working limits are to be established.

[39] Fifteen seconds is a general rule of thumb but can vary from agency to agency.

- The engineer will make movements only as permitted by the employee in charge until the working limits have been released to the engineer.
- The train will not release its authority within the limits until those working limits have been released by the EIC.

See Appendix C for more detail.

Exclusive Occupancy

Exclusive track occupancy is used to establish working limits on controlled tracks and is requested by the EIC and issued by the train dispatcher. When exclusive occupancy has been established, train movement on the segment of roadway worker-occupied track is held clear by the authority of the dispatcher. The procedure depends upon communication of precise information between the train dispatcher, the roadway worker in charge of the working limits, and the crews of affected trains. See Appendix C for more detail.

Track Bulletin

Track Bulletin protection is a method of establishing roadway worker protection by filing a track bulletin (Form B in GCOR) with the train dispatcher. Under most circumstances, a track bulletin is required to be submitted to the train dispatcher no less than 24 hours in advance. A track bulletin establishes working limits for the roadway work crew by identifying:

- Subdivision
- Specific work limits
- Start and finish time
- Track(s) affected
- EIC, Foreman, and roadway work crew names

See Appendix C for more detail.

Joint Occupancy

Joint Occupancy is the process by which a separate roadway work group is afforded on-track safety by the EIC of a pre-established exclusive track occupancy and located away from the EIC of the pre-established exclusive track occupancy. If Positive Train Control (PTC) is available, then PTC system components enforce train Movement Authority (MA) limits and provide train crew information. See Appendix C for more detail.

Justifications for an RWP Safety System

A roadway worker must complete on-track safety training and railroad operating rules training before being allowed to perform work. Even with appropriate training, there is potential for accidents that could cause injury, damage to equipment, and potentially death. To identify the hazards associated with roadway workers, a hazard/risk analysis should be conducted based on the RWP Use Cases in Appendix C. This analysis can identify hazards still present to a roadway worker even when following all rules and training. An RWP safety system is intended to supplement safety for RWP in addition to following safety rules and protocols.

Potential Roadway Work Risks

An RWP safety system can be developed to prevent potential roadway worker hazards, which fall into the following four categories and how an RWP safety system may help to mitigate these risks:

- Miscommunication – A misunderstanding of, or error in, communications between the roadway worker, EIC, train crew and/or dispatcher. The miscommunication may be the error of any of the parties involved.
- This hazard could be minimized by an RWP safety system that can identify the exact location of each of the roadway crew members to the EIC.
- Inattention – A lack of attention to the current working situation by the roadway worker, Watchman, EIC, train crew and/or dispatcher.
- This situation could be mitigated by the watchman using the Train Approach Detection Concept. A train alert sent from such a safety system would allow the workmen enough time to get in the clear of the track before the arrival of the train.
- Incorrect Individual Train Detections (ITD) assessment – ITD is a procedure by which a Lone Worker or Watchman/Lookout acquires on-track safety by determining they have adequate sight distance to see approaching trains and clear the track no less than 15 seconds before a train arrives at their location (generally 15 seconds but can vary from agency to agency). Before beginning work on track, the roadway worker or EIC has the responsibility of performing an ITD assessment. This assessment has the potential for human error. An example of this is not adequately assessing sight distance available from the intended work zone.
- This situation could be potentially mitigated by an RWP safety system by providing the exact location of the train to the lone worker before he/she entered the foul limits of the track. An example of such a safety system designed to provide this information to the roadway worker is the High Accuracy Train Location.
- Workmen Incapacitated – A workman is physically unable to clear the track. This has the greatest potential risk in a Lone Worker situation.
- Although an RWP safety system may not be able to alert an incapacitated worker of a train approach due to their physical state, it may be able to

provide information to the EIC indicating that the workman has not cleared the track by providing the workman's GPS location. For example, if a roadway work crew is working under Exclusive Track Occupancy and the authority is nearing its end time granted by the dispatcher, the EIC will radio each member of the work crew to notify them to clear track. Each workman will then radio the EIC to confirm they have cleared the foul of the track. If a workman working in a remote location is not able to answer the EIC's call to the clear the track, the Worker Position Monitoring concept would be able to provide the GPS location of the incapacitated workman to the EIC. This will allow the EIC to more efficiently keep track of the workers and act more immediately if one fails to respond when a call to clear is made.

Potential Benefits

The addition of an RWP safety system working in conjunction with established RWP safety training and rules has the potential to greatly enhance situational awareness of roadway workers. With the use of several potential concepts, a safety system provides roadway workers with information about the position of trains and other roadway workers. Such a safety system would also provide an additional means of communication among roadway workers. Alerts from the system would give workers an audible, visual, and physical alert to make them aware of potentially dangerous situations. Table D-1 gives a high-level overview of potential benefits to the safety of roadway workers. Risk reduction concepts are explained in more detail in Section 4.

Table D-1 *Benefits of RWP Safety System*

Risk	Risk Reduction Concept	Benefit
Environmental conditions, such as weather or time of day results in a reduction in sight distance that is not recognized by a lone worker.	Train Approach Detection Alarm	Worker provided with additional audible, visual, physical notification of train approach, improving situational awareness and reducing the occurrence rate of incident
Workman moves outside of working limits.	Roadway Worker Position Monitoring	Worker provided accurate location of working limits and alerted when encroaching upon them
Watchman fails to notice train approaching due to inattention	Train Approach Detection / Watchman Warning System	Watchman/Worker provided with additional audible, visual, physical notification of train approach. Watchman/Workman communication enhanced.
Exclusive Track Occupancy (ETO) issued with incorrect work limits	Train Position Concept	EIC provided access to information as input by dispatch, able to verify ETO was entered as requested prior to occupying track.
High speed train approach on track A while roadway workman on Track B	High Accuracy Train Position	Roadway workers provided with information about train approach on adjacent track; improved situational awareness.

Concept of Operation of RWP Safety System

The proposed concept of operation (CONOPS) for an RWP safety system is not a single system; rather, it is a set of risk-reducing concepts intended to improve roadway worker safety by reducing specific risks. The intent of this CONOPS is to provide information to roadway workers that will further enhance situational awareness when in a situation identified by the PHA. However, such a system as laid out in this CONOPS cannot pass critical information to a roadway worker. Therefore, this CONOPS should not be considered a fail-safe system but rather a non-vital collection of operational data accessible to roadway workers and not a replacement of current roadway operating and safety rules. Current roadway operating rules must remain in place and continue to be followed. Not all capabilities described in this section are intended to work simultaneously in a single system. The intention of this CONOPS is to allow roadway workers to select a concept that provides the most applicable data to the work situation.

System Constraints

The constraints of an RWP safety system as laid out in the CONOPS are centered on the communication platform and human factors. These constraints include but are not limited to the following:

- The system relies on wireless data communications such a Wi-Fi, cellular, and 220MHz where available for system updates.
- The system is not a fail-safe system architecture; if it fails to provide information to a roadway worker, it must be able to provide an audible, visual, and physical alarm to them to inform them of the loss of communications and to clear the track.
- The alert device battery life and/or system functions when battery life is nearly depleted could also be considered a constraint for such a system.
- The system is itself not able to force a roadway worker out of a hazardous situation. Its intention is to provide useful data and alerts to the roadway worker, allowing them to avoid or mitigate a hazardous situation.

CONOPS of RWP Safety System

This section describes the CONOPS that include risk reduction concept functions and how it may be used in conjunction with current roadway operating rules to enhance the safety of the roadway worker.

Train Location Concept

The Train Location Concept uses a mobile device used by roadway workers to receive information about train location and will display a subdivision schematic with track block occupancy information. The display will be similar, if not the same, as that used by dispatchers. Block occupancy information will provide the roadway worker general information about train location. The track block information can be used by the roadway worker or watchman to determine, with some level of accuracy, when a train may begin to occupy the block in which they are working, or proceeding block, as appropriate to the work location. The information will supply the roadway worker with an early warning of a train approach. However, it will still be incumbent upon the roadway worker to maintain situational awareness, as this concept will not inform of precise train location with respect to their current position.

The main benefit of this concept is that it provides roadway workers with an improved awareness of train block occupancy with respect to their work location via a handheld or worn alerter. The concept requires a communication link to provide updates of track occupancy data to the roadway worker. This dependency on a communication link could allow the concept to not function if there is a loss of communication with cellular or radio signal. The loss of communication in a concept of this architecture will result in the roadway worker having stale data. This concept is not fail-safe in design. Figure D-1 shows a potential communication architecture for this concept. An example of how this Train Location Concept might be used is provided in Table D-2. The information is an example of how this concept could be used in the situation of Use Case UC-RWP-105 from Appendix C.

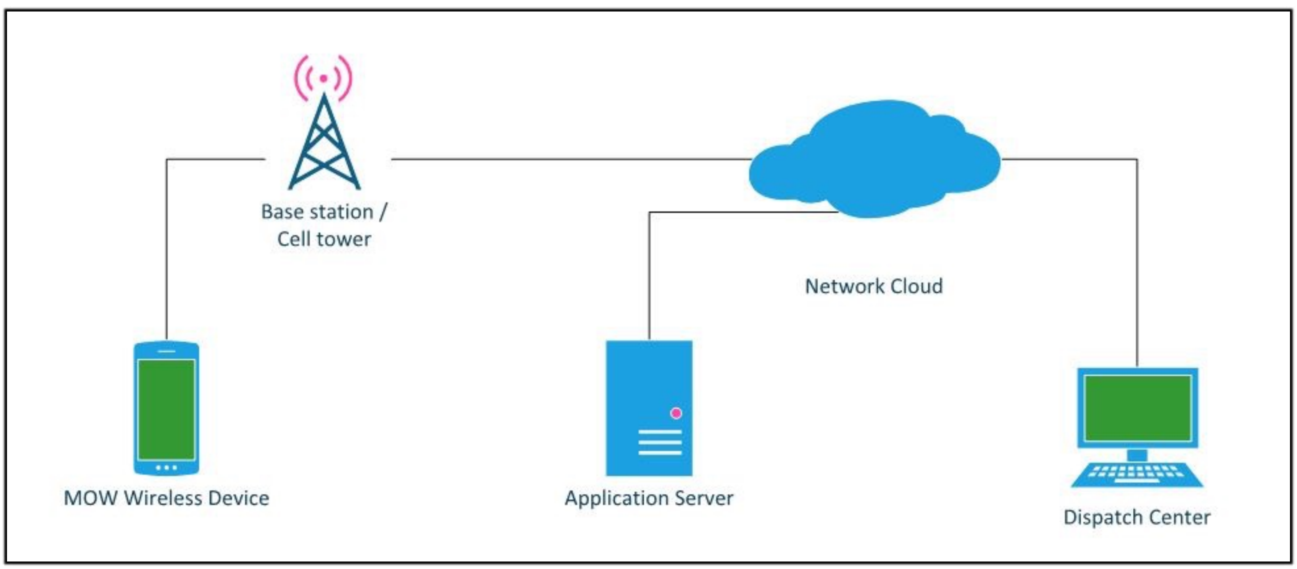


Figure D-1 *Train Location Concept*

Table D-2 *Train Location – Lone Worker Double Track*

ID	UC-RWP-105
Title	Lone Worker with Train Location Concept – Double Track
Description	Lone Worker must foul track Main 1 to perform inspection or minor adjustment/ repair. Lone Worker is equipped with the Train Location Concept. Road train on track Main 2 approaches work area.
Method of Operation	Any
RR Personnel	LW, TC
RR Systems	Road Train
Reference Track Configuration	Double track per section 4.1.5.
Initial Condition	1. LW determines maximum train speed. 2. LW determines clear time. 3. LW determines sight distance available. 4. LW determines sight distance required. 5. Track Main 1 to be accessed by LW is unoccupied. 6. Lone worker verifies CONOPS Concept is active and determines train location 7. LW accesses track Main 1 and begins work if ITD is acceptable.
Trigger Event	Road train on track Main 2 approaches track segment occupied by LW.
Scenario Steps	1. LW observes Train Location Concept display that shows train occupancy in nearby signal block, focusing LW attention of train approach. 2. LW observes road train approaching. 3. TC blows whistle. 4. LW clears track Main 1. 5. TC proceeds through track Main 2 segment.
End State (Happy Path)	1. LW cleared track. 2. Road train proceeded.

Train Approach Detection Concept

The Train Approach Detection Concept is designed to provide the roadway worker with notification of an approaching train. This concept integrates a set of train approach indicator devices that can be installed on or near the track to signal the roadway worker and/or the EIC of an approaching train. The train presence detectors need to be temporally installed in the same way flags are installed at the ends of a roadway work zone. Once installed, the device will send a heartbeat signal to a concept used by the roadway worker. The persistence of this heartbeat, or continual link, between the train presence detectors and the roadway worker concept will indicate that no train is present. When a train enters the safe stop area of the roadway work zone the device would stop the heartbeat. The loss of the “no train present” heartbeat will signal the device to alert the roadway worker of train presence or loss of heartbeat. The concept is not fail-safe overall, however, because it relies on the use of a battery-operated alert device to be worn by the roadway worker. Some of the drawbacks to this concept would include:

- The device must be installed on the track prior to beginning work
- The concept would require a secure signal between the train presence device and the roadway concept
- Loss of signal would trigger false alarms
- The potential still exists for the train presence device to be placed in an incorrect position/location on track

This concept is relatively simple in design and is a closed loop system. It would not depend on any communication with the Back Office to function. This concept is not fail-safe in design due to its dependency on a battery-operated alert device. Figure D-2 details a potential communication architecture for this concept. An example of how this Train Approach Detection Concept might be used is provided in Table D-3. The information is an example of how this concept would be used in the situation of Use Case UC-RWP-208 from Appendix C.

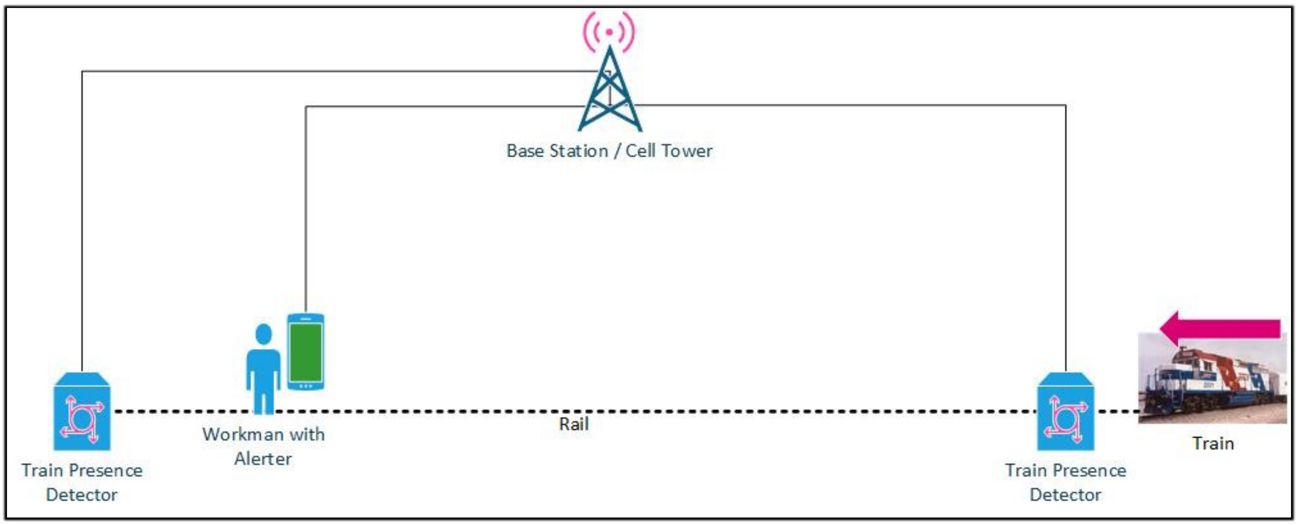


Figure D-2 *Train Approach Detection Concept*

Table D-3 *Train Approach Detection Concept / Watchman/Lookout Triple Track*

ID	UC-RWP-208
Title	Watchman/Lookout with Train Approach Detection Concept – Triple Track
Description	Roadway worker(s) under same WLP must foul track Main 3 to perform adjustments and/or minor repairs. Watchman is equipped with High Accuracy Train Location Concept. Road train on track Main 2 approaches work area.
Method of Operation	Any
RR Personnel	WM, roadway Worker(s), TC
RR Systems	Road Train
Reference Track Configuration	Triple track per section 4.1.8.

Initial Condition	1. WM determine maximum train speed for approaches to work area. 2. WM obtain clear time estimate from roadway worker(s). 3. WM determine sight distance available. 4. WM determine sight distance required. 5. WM briefs roadway worker(s) on conditions (i.e. train speed, clear-to location(s), etc.) 6. WM to get in appropriate position to watch for trains and alert roadway worker(s) of approaching train. 7. Track Main 3 to be accessed by roadway worker(s) is unoccupied by train or other vehicles. 8. Roadway worker(s) deploy Train Detection sensors on Track Main 3 and verify that the concept is functioning. 9. Roadway worker(s) access track Main 3 and begin work.
Trigger Event	Road train on track Main 2 approaches track segment occupied by roadway worker(s). *Note: Scenario is the same as double track if train is approaching on same track or track adjacent to track occupied by LW.*
Scenario Steps	1. WM observes road train approaching. 2. TC observes roadway worker(s) and blows whistle. 3. WM determines road train not on same track or adjacent track. 4. Roadway worker(s) do not clear track. 5. Road train proceeds past work area track segment.
End State (Happy Path)	1. WM and roadway worker(s) continue work. 2. Road train proceeds.

Watchman Warning System Concept

The Watchman Warning System Concept is designed to allow better communication between a watchman and roadway workers on track. The concept could be particularly useful in situations in which watchman and roadway worker visibility are impaired by weather or terrain. The concept is designed as a closed loop secure commination system. To function, each member of the roadway work group, as well as the watchman, are required to wear a communication/alerting device. When deployed, each roadway worker will need to pair communication with each watchman. A watchman would then be able to send an alert signal to all roadway workers to clear track as well as receive an all-clear signal in return from each roadway worker. The device worn by the roadway worker will be equipped with audible, visual, and physical alerts. This concept functions by sending a heartbeat shared between each of the members of the roadway work crew. The device communication is fail-safe because the alert is triggered by loss of “all clear” heartbeat sent from the watchman. In the event of loss of communication or termination of this heartbeat by the watchman or any roadway worker, an alert to clear track will be sent to every member of the roadway work crew. The Watchman Warning Device will produce a visual, audible, and physical alarm. Due to the battery-operated alert device worn by the roadway worker, the overall concept cannot be considered fail-safe. Figure D-3 depicts the communication architecture of the Watchman Warning System Concept. An example of how this concept might be used is provided in Table D-4. The information is an example of how this concept would be used in the situation of Use Case UC-RWP-201 from Appendix C.

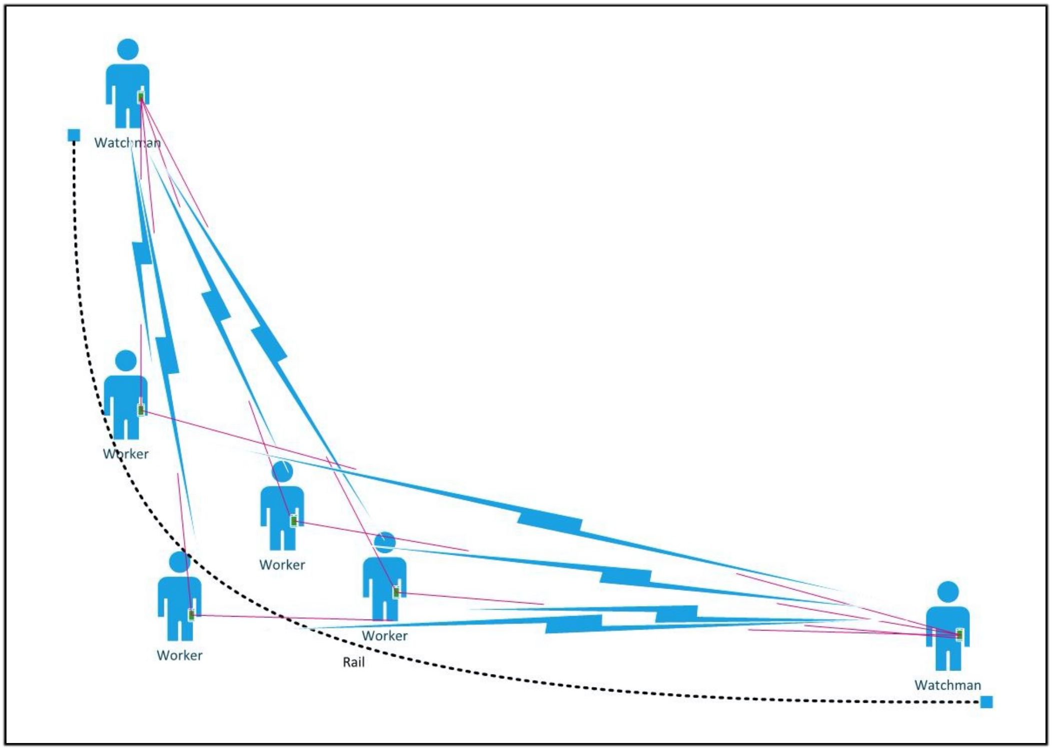


Figure D-3 *Watchman Warning Concept*

Table D-4 *Watchman Warning Concept/Watchman/Lookout Single Track*

ID	UC-RWP-201
Title	Watchman/Lookout with Watchman Warning Concept– Single Track
Description	Roadway worker(s) under same WLP must foul Main track to perform adjustments and/or minor repairs. Watchman is equipped with Watchman Warning Concept. Road train on Main track approaches work area.
Method of Operation	Any
RR Personnel	WM, roadway worker(s), TC
RR Systems	Road Train
Reference Track Configuration	Single track per section 4.1.1.
Initial Condition	1. WM determine maximum train speed for approaches to work area. 2. WM obtain clear time estimate from roadway worker(s). 3. WM determine sight distance available. 4. WM determine sight distance required. 5. WM briefs roadway worker(s) on conditions (i.e., train speed, clear-to location(s), etc.) 6. WM to get in appropriate position to watch for trains and alert roadway worker(s) of approaching train. 7. Main track to be accessed by roadway worker(s) is unoccupied by train or other vehicles. 8. Watchman/Workmen perform system function test to assure the Watchman Warning Concept is working properly. 9. Roadway worker(s) access track and begin work.

Trigger Event	Road train approaches track segment occupied by roadway worker(s).
Scenario Steps	1. WM observes road train approaching. 2. TC observes roadway worker(s) and blows whistle. 3. WM alerts roadway worker(s) of approaching road train but verbally and via Watchman Warning Concept. 4. Roadway worker(s) clear track, to include any tools that may be in the foul. 5. Road train proceeds through track segment.
End State (Happy Path)	1. WM and roadway worker(s) cleared track. 2. Road train proceeds.

Roadway Worker Position Monitoring Concept

The Roadway Worker Position Monitoring Concept is designed to help keep safe roadway workers working within the limits of the assigned track authority bulletin. The concept works in conjunction with a device worn by the roadway worker designed to alert them when they are encroaching on the limits of the track authority. When the EIC requests authority to work on track, the working boundaries will be defined and entered as part of the granted authority. These boundaries will then be enforced by the roadway Worker Position Monitoring concept. When the roadway worker approaches the end of the track authority limits, they will receive a boundary alarm. The alarm will be visual, audible, and physical to ensure the highest potential for the roadway worker to receive the alarm. The main benefit of the roadway Worker Position Monitoring concept is its ability to enhance the roadway worker's awareness of the track authority limits they are working under. Potential drawbacks of the concept include:

- Potential for roadway worker to not receive alerts
- Alert device battery life
- Potential for device to lose GPS signal
- Potential for roadway worker to begin work without donning the device
- Nuisance alarms generated when roadway worker leaves the perimeter of the track authority purposely for a legitimate reason

This concept is not fail-safe in design. Figure D-4 depicts a potential communication architecture of the Watchman Warning System Concept.
An example of how this concept might be used is provided in Table D-5. The information is an example of how this concept would be used in the situation of Use Case UC-RWP-701 from Appendix C.

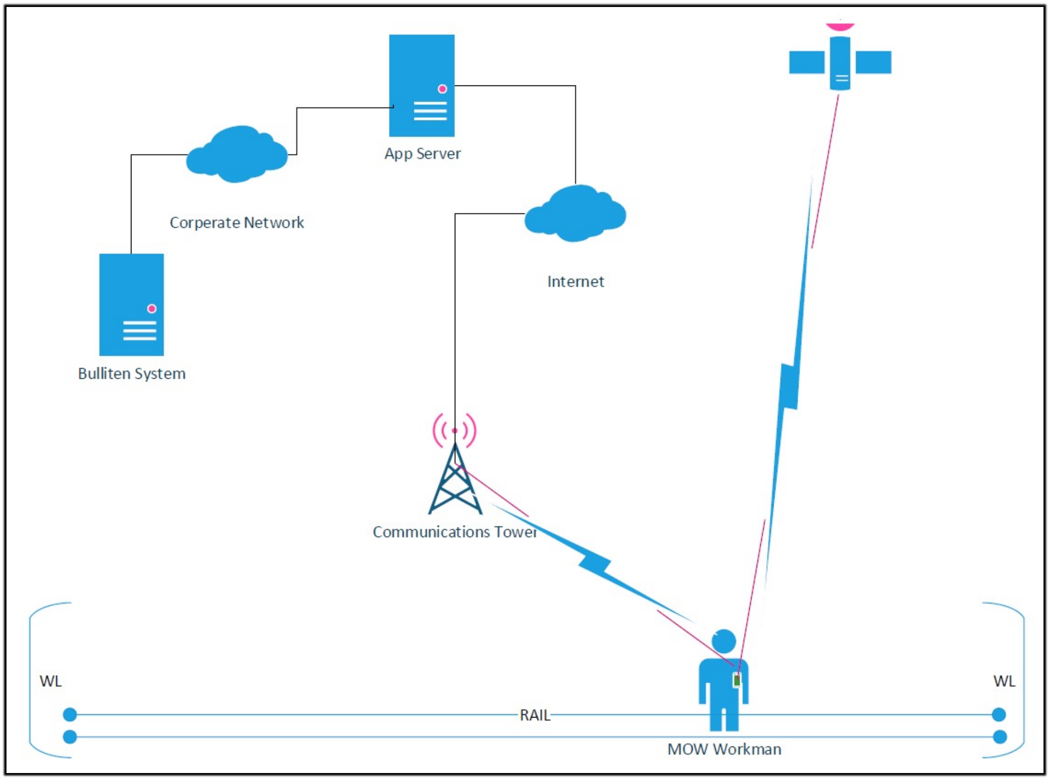


Figure D-4 *Roadway Worker Position Monitoring Concept*

Table D-5 *Roadway Position Monitoring / Track Bulletin Single Track*

ID	UC-RWP-701
Title	Track Bulletin – Single Track with Roadway Worker Position Monitoring Concept
Description	Track bulletin used to provide protection to roadway worker(s) accessing Main track; roadway worker equipped with Worker Position Monitoring device encroaches on bulletin limit
Method of Operation	TB
RR Personnel	EIC, Roadway Worker(s), Train Crew
RR Systems	DBO, Road Train, Onboard
Reference Track Configuration	Single Track per section 4.1.1.
Initial Condition	1. EIC of roadway worker(s) obtains TB on Main track between WL_A and WL_B per UC-RWP-308. Authority limits added to the track bulletin system 2. Roadway worker(s) access Main track, as defined in TB.
Trigger Event	Road Train approaches end of MA at WL_A on Main track.

Scenario Steps	1. TB provided to TC of Road Train at initial station unless otherwise instructed by dispatcher. 2. Onboard displays end of MA at WL_A to TC. 3. TC of Road Train contacts EIC and requests permission to proceed beyond WL_A. 4. TC stops Road Train short of WL_A. 5. EIC denies TC permission past WL_A. 6. Roadway worker(s) don roadway Position Monitoring device and access Main track within track segment AB until work is complete. 7. Roadway worker encroaches into track bulletin authority limits due to disorientation. 8. Roadway worker receives perimeter alarm from roadway Position Monitoring device 9. Roadway worker moves back into safe area of track bulletin 10. Upon completion of work, roadway worker(s) clear themselves and equipment from Main track. 11. EIC verifies all roadway worker(s) are clear of track segment AB. roadway workers power down roadway Position Monitoring device. 12. EIC contacts TC of Road Train and grants permission to proceed beyond WL_A through work zone at a given speed. 13. Onboard releases enforcement of WL_A.
End State (Happy Path)	1. Roadway worker(s) are clear of Main track segment AB. 2. Road Train proceeds into Main track segment AB.

Abbreviations and Acronyms

APTA	American Public Transit Association
ATC	Autonomous Train Control
ATO	Automatic Train Operation
BOS	Back Office Server
CAD	Computer Aided Dispatching
CFR	Code of Federal Regulations
CONOPS	Concept of Operations
CP	Control Point
CRM	Continuous Risk Management
CTC	Centralized Traffic Control
CUTR	Center for Urban Transportation Research
DBO	Dispatch Back Office
EIC/RWIC	Employee in Charge/ (Roadway Worker in Charge)
EOA	Exclusive Occupancy Authority
ETA	Estimated Time of Arrival
ETO	Exclusive Track Occupancy
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GCOR	General Code of Operating Rules
GPS	Global Positioning System
ITD	Individual Train Detection (Lone Worker)
JO	Joint Occupancy
JOP	Joint Occupancy Protection
LW	Lone Worker
MA	Movement Authority
MOW	Maintenance of Way
MWI	Maintenance of Way Instruction
NASA	National Aeronautics and Space Administration
NORAC	Northeast Operating Rules Advisory Committee
NRC	Nuclear Regulatory Commission
NTD	National Transit Database
NTSB	National Transportation Safety Board
PHA	Primary Hazard Assessment
PPOS	Predetermined Place of Safety
PSF	Performance Shaping Factors
PTC	Positive Train Control
RAIB	Rail Accident Investigation Board
RIDM	Risk Informed Decision Making
RR	Railroad
RTA	Rail Transit Agency
RTO	Remote Train Operation

RWIC/EIC	Roadway Worker in Charge/Employee in Charge
RWP	Roadway Worker Protection
SMS	Safety Management System
SOP	Standard Operating Procedure
TAW	Train Approach Warning using a watchman/lookout
TB	Track Bulletin
TC	Train Crew
TO	Train Operator
TW	Track Warrant
TWC	Track Warrant Control
TTC	Transportation Technology Center (the site)
TTCI	Transportation Technology Center, Inc. (the company)
UC	Use Case
WKL	Working Limits
WL	Watchman/Lookout
WLP	Watchman/Lookout Protection
WM	Watchman

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