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An Investigation of the Effects of Positive Train Control Systems on Track Maintenance

DOT/FRA/ORD-24/32

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14. ABSTRACT

The Federal Railroad Administration (FRA) contracted Transportation Technology Center, Inc. (TTCI) to conduct a broad analysis of the impacts of Positive Train Control (PTC) systems and technology on track maintenance. This research was conducted between September 2019 and September 2020. This report documents the activities of the effort, including a review of the project objectives, an overview of PTC systems and technology in the context of track maintenance and roadway worker protection (RWP), and an analysis of the potential areas that PTC might affect track maintenance. In coordination with FRA, TTCI generated a list of possible effects of PTC on track maintenance to guide the research.

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

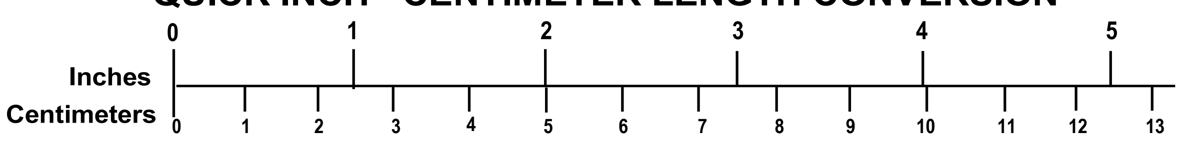
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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Executive Summary

The Federal Railroad Administration (FRA) contracted Transportation Technology Center, Inc. (TTCI) to conduct a broad analysis of the impacts of Positive Train Control (PTC) systems and technology on track maintenance. This research was conducted between September 2019 and September 2020.

This report documents the activities of the effort, including a review of the project objectives, an overview of PTC systems and technology in the context of track maintenance and roadway worker protection (RWP), and an analysis of the potential areas that PTC might affect track maintenance. In coordination with FRA, TTCI generated a list of possible effects of PTC on track maintenance to guide the research. These topics included:

- PTC critical assets, databases, change management, and use of the data
- RWP under PTC and track access for maintenance of way (MOW) work
- Avoiding complacency and confusion around what PTC does and does not do for MOW workers in various RWP scenarios.
- MOW rule changes or training changes resulting from PTC
- The types of MOW equipment or trains equipped with PTC (small and large MOW equipment, hi-rail trucks, ballast, rail, or tie car trains, etc.)
- Emerging technologies and opportunities to improve track maintenance and RWP in the era of PTC.

TTCI conducted interviews and gathered information from railroads affected by PTC. Specifically, it contacted railroad representatives with maintenance-of-way (MOW) experience and related job duties to assess the impact of PTC technology on their areas of responsibility. Also, researchers consulted TTCI's PTC subject matter experts to learn more about PTC's impact on MOW activities.

The following summarizes the key findings and conclusions from this study:

- The largest and most significant effect that PTC has had on track maintenance has been the need to manage and communicate changes to PTC critical assets during typical MOW work. Many PTC critical assets are managed by MOW departments. When an asset location is changed, it must be reported and resurveyed to update the PTC critical asset database.
- All respondents reported having a change management process in place to handle changes in location to PTC critical assets. There appear to be various reporting systems and approaches to managing critical asset location changes depending on the size of the railroad and the number of critical assets controlled.
- In general, there was an emphasis on the change management process of critical assets that are more easily relocated in the field (e.g., milepost signs, yard limit signs, or block limit signs).

- No changes to RWP practices were reported as a result of PTC. Other than the key impact of PTC enforcing a stop and preventing the incursion of a train into an established work zone (e.g., exclusively occupied track), PTC has no other impact on RWP and is transparent to MOW workers.
- The basic principles of RWP – *to expect a train in any direction, on any track, and at any time* – have not changed. RWP protection situations not known to the train control system, such as watchman lookout protection or lone worker protection, are unaffected by PTC.
- It is important to recognize the need for roadway workers to avoid any sense of complacency or a false sense of security under PTC. Knowing what PTC does, but more importantly, what it does not do for a roadway worker is paramount.
- While some railroads did report difficulty accessing track for track maintenance, these issues were directly related to the rollout and debugging of PTC. PTC, as being implemented, should not inherently have any impacts on track access, availability, or duration to perform maintenance.
- There were no reports of MOW rule changes implemented as a result of PTC. Many respondents indicated an emphasis on the importance of reporting critical asset locations changes as necessary.
- PTC has not had any impact on MOW trains or MOW equipment. Large MOW trains still operate under similar protection as before PTC. MOW equipment is not equipped with PTC; however, some railroads reported interest in "PTC-like" systems for hi-rail trucks and MOW equipment. Such systems provide an alarm/alert for MOW vehicles reaching the limits of their authority and are not tied into the throttle or braking systems of the vehicle.

The PTC era has brought about technologies and future opportunities that could improve the safety of common track maintenance responsibilities. These include critical alerts (e.g., rail temperature, severe weather), PTC-like systems for MOW equipment and hi-rail trucks, Employee-in-Charge Portable Remote Terminal (EIC-PRT) systems to facilitate EIC communication with locomotives moving through an EIC-controlled section of track, and track monitoring systems integrated with PTC.

Future research could include a study into these emerging technologies, how they could be implemented, and what impact they would have on track maintenance and overall infrastructure management.

1. Introduction

The Federal Railroad Administration (FRA) contracted Transportation Technology Center, Inc. (TTCI) to conduct a broad analysis of how Positive Train Control (PTC) systems and technology affect track maintenance. TTCI performed this research between September 2019 and September 2020. TTCI conducted interviews with various types and sizes of railroads affected by PTC, and this report summarizes the investigation.

1.1 Background

In 2008, Congress passed the Rail Safety Improvement Act of 2008 (RSIA '08), which required railroads to install PTC on track that carries passengers and certain hazardous materials. Myriad other projects and studies have described the expected effects of PTC on general railroad operations. However, the effect of PTC implementation and PTC technologies on track maintenance practices has not yet been formally documented from a general industry perspective. Section 2 is devoted to a primer on the background of PTC and the important elements of the technology related to track infrastructure.

1.2 Objectives

The objective of this project was to complete a broad analysis of the impacts of PTC on track maintenance and determine if there are gaps that need to be filled to effectively integrate track maintenance activities in PTC-controlled territories. Both technical and human factors are assessed.

1.3 Overall Approach

This research project analyzed the effects of both existing and potential PTC implementations on track maintenance activities. Using TTCI's Communications and Train Control engineers, PTC experts, and track maintenance experts in conjunction with discussion and information gathered from U.S. passenger and freight railroad owners/operators impacted by PTC, a body of knowledge was developed and is presented in this report. The researchers first sought to understand the basics of PTC and the interaction of PTC with track maintenance practices. Then, discussions and information-gathering from railroad representatives focused on how maintenance of way practices have been affected by the implementation of PTC. Key topics include the extent to which PTC has affected track maintenance personnel, track maintenance efficiency and timelines, RWP, and asset management/asset databases.

1.4 Scope

The discussion of the scope of PTC is purposely limited to the basic characteristics necessary to understand its effect on track maintenance. This project did not address PTC system technical details and safety analyses since other projects have examined those issues.

1.5 Organization of the Report

Section 2 provides a primer on PTC in the context of track maintenance. Section 3 summarizes the interviewing and information gathering process about what potential areas or categories of PTC might affect track maintenance activities. Section 4 specifically addresses the effects of PTC on RWP. Section 5 discusses the results of the study and presents conclusions. Another important part of this project was to document emerging technologies and opportunities for improved MOW safety in the PTC era, which Section 6 discusses. Appendix A lists the PTC affected railroads that TTCI contacted, and Appendix B outlines FRA's RWP requirements.

2. Overview of Positive Train Control

This section is intended as a high-level overview of PTC. For this project, the explanations of PTC functionalities are not intended to cover the detailed system or regulatory PTC requirements. The regulatory requirements for PTC can be found in the Code of Federal Regulations (CFR), Title 49, Subtitle B, Chapter II, Part 236, Subpart I – Positive Train Control Systems (CFR, 2010). The scope of this project is limited to understanding the effects of PTC on track maintenance practices. To fully grasp those effects, an overview of PTC, how it works, and how various track maintenance practices interact with PTC are described in this section. A description of how MOW (roadway) workers are protected from trains, how trains are protected from track made unsafe for passage on tracks undergoing repairs, and the requirements of the FRA's Roadway Worker Protection Requirements (CFR, 1996), is provided in Appendix B.

2.1 What is PTC?

PTC is a safety system that tracks the speed and movement of trains and can automatically stop a train to prevent specific human-error accidents. The Rail Safety Improvement Act of 2008 requires that PTC prevent four specific types of incidents. 49 CFR §236.1005(a) – Requirements for Positive Train Control states:

"PTC system requirements. Each PTC system required to be installed under this subpart shall:

(1) Reliably and functionally prevent:

(i) Train-to-train collisions—including collisions between trains operating over rail-to-rail at-grade crossings in accordance with the following risk-based table or alternative arrangements providing an equivalent level of safety as specified in an FRA approved PTCSP;

(ii) Overspeed derailments, including derailments related to railroad civil engineering speed restrictions, slow orders, and excessive speeds over switches and through turnouts;

(iii) Incursions into established work zone limits without first receiving appropriate authority and verification from the dispatcher or roadway worker in charge, as applicable and in accordance with part 214 of this chapter; and

(iv) The movement of a train through a main line switch in the improper position as further described in paragraph (e) of this section." (CFR, 2010)

PTC is not a brand name or technology; it is whatever system is used to comply with the regulation, as approved by the FRA. PTC technology includes brand names given by suppliers and colloquial names applied by railroads in the context of this document and the FRA regulations. Some of the various technical names of the various approaches and technologies used to meet FRA PTC requirements (Federal Railroad Administration (FRA), 2019) include:

- ACSES (Advanced Civil Speed Enforcement System)
- ASES (Advanced Speed Enforcement System)

- CBTC (Communications-Based Train Control)
- E-ATC (Enhanced Automatic Train Control)
- ETMS (Electronic Train Management System)
- I-ETMS® (Interoperable Electronic Train Management System, Wabtec Corporation)
- I-ITCS (Interoperable Incremental Train Control System)
- ITCS (Incremental Train Control System)
- SafeNet™ System – Argenia Railway Technologies
- Trainguard® Sentinel System – Siemens AG

2.2 Where is PTC Required?

"PTC is required to be installed and implemented on Class 1 railroad main lines (i.e., lines with over 5 million gross tons (MGT) annually) over which any poisonous- or toxic-by-inhalation (PIH/TIH[1]) hazardous materials are transported; and, on any railroad's main lines over which regularly scheduled passenger intercity or commuter operations are conducted." (Federal Railroad Administration, 2019)

In summary, PTC is required on:

- Class I railroad main tracks, which:
  - Exceeds 5 million gross tons (5 MGT[2]) annual traffic
  - Handles PIH/TIH traffic
- Any railroad providing or hosting intercity or commuter passenger service.

The full requirements for where PTC must be implemented and the limited exceptions can be found in CFR 49, Subtitle B, Chapter II, Part 236, Subpart I, §236.1005 - Requirements for Positive Train Control Systems (CFR, 2010).

The FRA regulations provide limited relief from PTC requirements only in specific narrow circumstances, where train operations present a "de minimis risk"[3] and can only be applied with the advance approval of FRA (FRA, 2014). These limited exceptions can be found in 49 CFR §236.1005 (CFR, 2010).

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1 PIH/TIH (poisonous- or toxic-by-inhalation) are hazardous commodities, including chemicals like chlorine gas and anhydrous ammonia, that pose elevated risks due to exposure and potential negative or life-threatening effect on populations.

2 MGT is a metric that describes the sum of the accumulative weight of all the trains, locomotives, and railcars that pass over a specific track, typically the sum over a year's time.

3 In this context "de minimis risk" means the risk of a PTC-preventable accident is negligible. "In other words, such exceptions must only cover situations where "the burdens of regulation yield a gain of trivial or no value" and should apply not "to depart from the statute, but rather [as] a tool to be used in implementing the legislative design."

2.3 How Does PTC Work?

PTC is currently implemented as an "overlay" supervisorial system. PTC does not run trains. PTC monitors the performance of certain manual human operations and only intervenes to stop a train if certain conditions are met.

PTC acts as an enforcement intervention system to *existing* train control systems. Thus, the current implementation of PTC is not a "stand-alone" system. The PTC overlay adds additional levels of safety for certain risks, but not all risks, related to railroad operations, particularly for certain human errors. These certain risks relate to the four types of incidents PTC is required to prevent. PTC is a complex system of various components that works together with wayside devices, the locomotive engineer, and the train dispatcher to provide oversight and enforcement (train stopping) where these certain conflicts could occur before they do occur.

PTC generally consists of the following four segments, as shown in the general schematic in Figure 1:

1. Onboard segment
2. Communications segment
3. Wayside segment
4. Back office segment

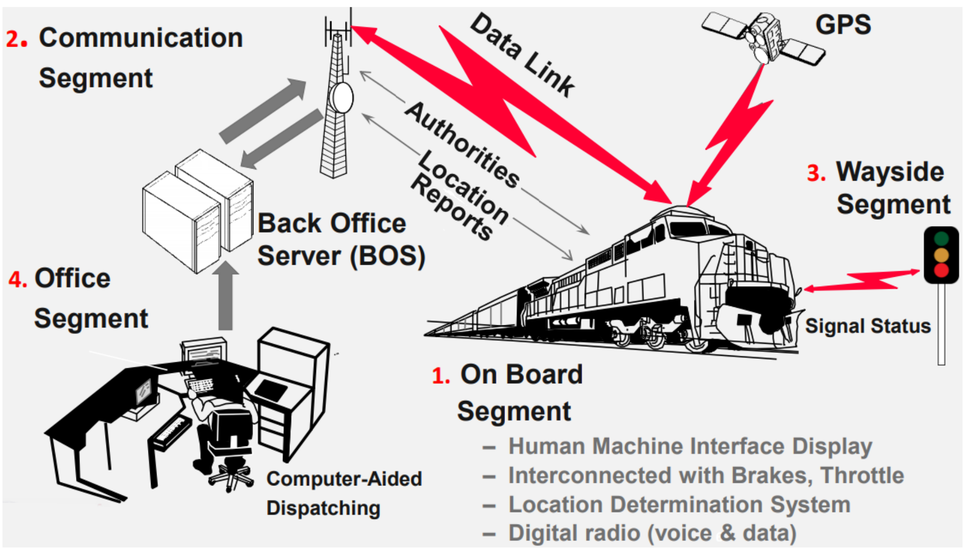

Figure 1. PTC Overview

The underlying concept of PTC is that the locomotive knows the following:

- Where it is (critical asset database)
- The train's braking characteristics (e.g., how long it will take to stop).
- Where, how far, and how fast it can go (movement authority and speed restrictions).

Using knowledge of these three items, PTC enforces limits to prevent violations without the ability to override.

2.4 PTC Critical Assets

For PTC to supervise train operations, a highly accurate digital map of each PTC-equipped route must be developed and maintained. This database of information (called "critical assets") includes the locations of key physical characteristics along a rail line. These assets, and their locations in space (linear locations along the track, typically collected using Global Positioning Systems (GPS) coordinate mapping) are used to develop the critical asset database. The PTC system does not enforce actions based on the actual physical location of critical assets; it acts upon where these critical assets are located in the critical asset database. Therefore, it is critical that:

- Assets are properly identified and located.
- Changes to the location of assets (e.g., during maintenance work) are updated in the PTC database in a timely manner.
- Periodic audits of critical asset locations are conducted to verify compliance.

If the location of a critical asset is incorrect, for example the location of a signal or a switch, a train could pass the location of a stop indication at that signal or that switch, with PTC unable to prevent it. Some discrepancies between track data and actual track characteristics encountered en route can cause unnecessary enforcements (train stops) or disengagements by PTC. Everything along the track that directly affects the safe operation of trains must be accurately located and uniquely identified. The following is a list of critical PTC assets:

- Track centerline (an imaginary line running the length of the track located at the midpoint between the rails)
- Permanent (civil) speed limits and speed restrictions
- Switches (devices that allow trains to change tracks)
- Fouling points (closest point on converging tracks where passing trains will clear each other)
- Derails (devices designed to purposefully derail a runaway car, before it fouls a main track)
- Milepost (MP) location signs
- Operational signs
- Signals
- Road crossings at grade

In the operation of PTC, the critical asset database is housed in the back office server (BOS). This data is uploaded to PTC equipped locomotives and updated when changes to the data occur. Critical assets are key components enabling PTC to enforce train movement authority and speed restriction start and end points. Without an accurate critical asset database, PTC could fail in its purpose. Critical assets are characterized by detailed and highly accurate surveying processes, validation, and auditing (double checking) processes, data standardization and formatting protocols (Association of American Railroads (AAR), 2014) that facilitate the sharing of data, which is critical to ensuring that trains from one railroad operating over another's track can understand the information.

Each critical asset element is mapped to indicate the point along the centerline of the track where the feature is located (see Figure 2).

Figure 2. Examples of Critical Assets and Locations

2.4.1 Crossing Diamonds and Movable Bridges

Crossing diamonds (where railroad tracks physically cross each other at the same grade) and movable bridges (bridges that lift the tracks out of the way of passing boats, making the track impassable to trains) were two track features discussed in the early phases of this project in regard to critical assets. Investigation of these special cases indicated that these assets are treated differently, as they are inherently protected by interlocking signals, derails, and in very limited cases, fixed operational signs. From a high level, PTC does not differentiate the authorities that it is enforcing, regardless of what it is, whether it be unintentionally encroaching into the location of another train, MOW crew, open bridge, or another location where a train does not have authority to move (see Figure 3).

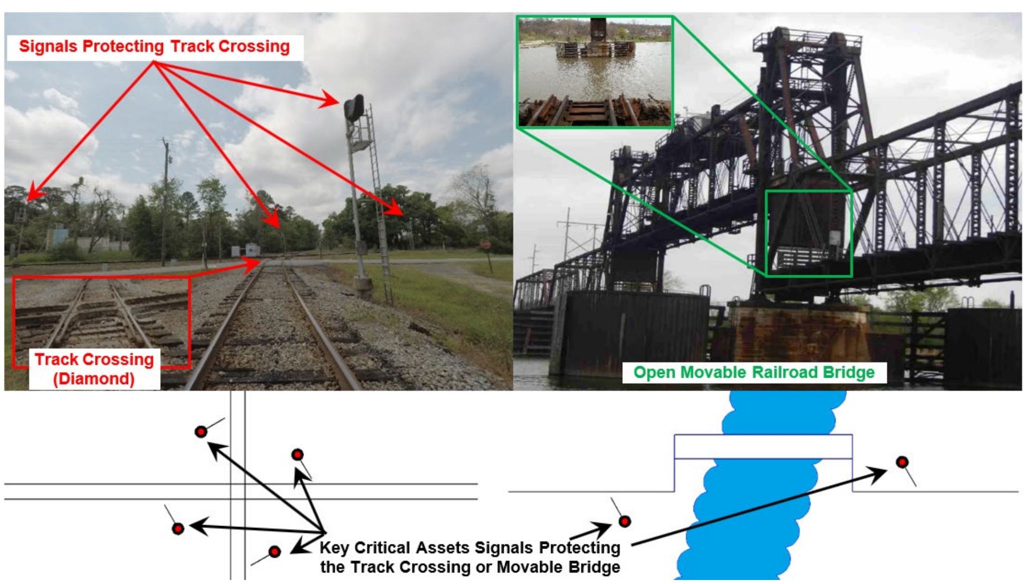

Figure 3. Crossing Diamond and Movable Bridge

2.4.2 Un-signaled Signage

Prior to PTC, the assets related to the movement of trains (e.g., signals) were typically maintained by signal department forces, exclusively. If signals were installed, moved, relocated, or changed, it was typically done through an engineering process entirely within the signal department management structure. Major changes that could affect others operating on the track (e.g., transportation and MOW) would be communicated through operational bulletins or other forms of formal notification. Trains and MOW personnel interact with this signage based on their physical location in the field, and not a pair of coordinates in a remote database.

With PTC, additional assets are now critical to the operation, and many of these assets are maintained by MOW departments. These include MP signs and operational signs (block limit signs, yard limit signs, etc.), as Figure 4 shows. These are not connected to the signal system and exist in the PTC critical asset database as a set of coordinates. In contrast to larger critical assets such as signals, switches, and at-grade road crossings that require extensive engineering and maintenance work to remove or relocate, critical assets such as MP signs and other operational signs can more easily be moved or removed by a single person without review and without database updates. This would create a disconnect between the location of the asset in the database and its physical location in the field. An example schematic of this is shown in Figure 5.

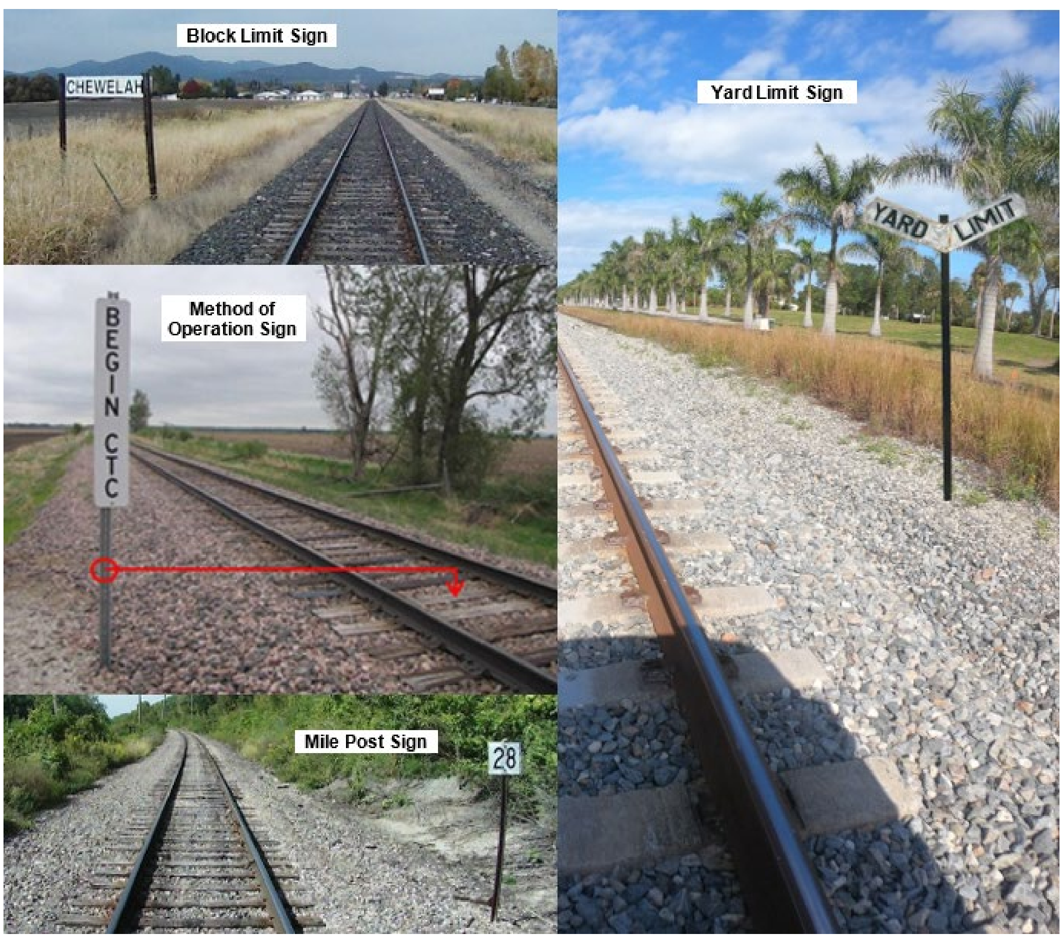

Figure 4. Critical Assets, Un-signaled Signage

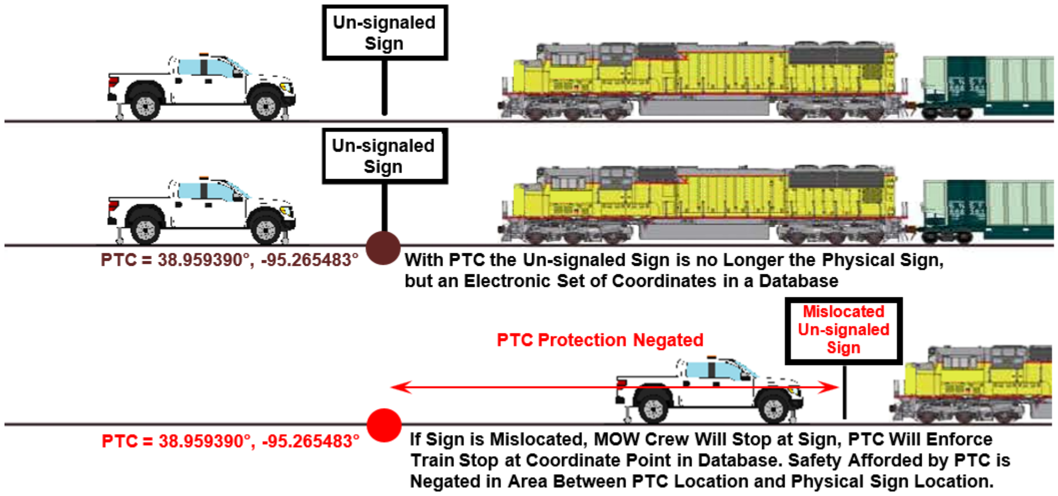

Figure 5. Critical Asset Relocation, Un-signaled Signage Example

These signs, and other track infrastructure critical assets, are generally installed and maintained by track MOW departments. As the installation, maintenance of, and movement of most of these critical assets fall under the jurisdiction of track maintenance departments, PTC maintenance is a primary topic to consider for this project. Section 3.3.2 discusses the management processes being employed by the railroads to ensure the proper locationing of critical assets in the database.

2.5 What PTC Does Not Do

PTC works to prevent or reduce the risks of incidents by mitigating certain human errors, such as incapacitated or inattentive train crew, but it is not an all-encompassing cure-all for all possible railroad incidents. PTC is not designed to prevent:

- Vehicle-train accidents at highway-railroad crossings
- Track or infrastructure failures
- Locomotive, railcar, or related equipment failures
- Low speed/restricted speed incidents[4]
- Train mishandling/train make-up
- Trespassers
- Trackway incursions
- Willful sabotage
- Natural disasters
- Incursions from trains/equipment on adjacent tracks

[4] Restricted speed is defined as “a speed that will permit stopping within one-half the range of vision not to exceed 20 mph.” As PTC does not have information on the range of vision (could be affected by weather, terrain, foliage, etc.), it can only enforce the upper limit of restricted speed.

- Employees not following safety rules when working around trains.
- Railroad personnel not following safety rules when fouling tracks.
- MOW personnel from being struck by MOW equipment
- Runaway cars/trains

3. Industry Interviews and Information-Gathering

TTCI's initial brainstorming and preliminary investigation included discussions and meetings with TTCI's track maintenance experts, RWP experts, and PTC experts. As part of these initial meetings and through the information-gathering activities with railroad representatives, the effects of PTC on track maintenance were categorized. These provided topics and questions to ask railroad representatives during the subsequent information-gathering phase of the project.

Appendix A lists the candidate railroads that TTCI attempted to contact during the interview process. This list was generated from the FRA/DOT – PTC Implementation Status by Railroad Report (FRA, 2018) and attempts were made to contact all the listed railroads. Not all railroads responded, however, a good cross-section of industry did.

The initial contact list was generated internally using contact information from TTCI personnel. In addition, the American Short Line Railroad Association and the American Public Transit Association assisted in providing additional contacts. Also, the American Railway Engineering and Maintenance-of-Way Association member list was used. Generally, the various railroads/entities were contacted via email with follow-up phone calls. In cases where no response was received, additional contacts were attempted.

The railroads were advised that the information they provided would be used anonymously and not associated with their specific railroads in any reports. In all cases, TTCI found the discussion with the various railroads to be open and candid. Many of the respondents had both engineering management and field experience, which provided excellent insight to the issues discussed. In some cases, the interviews were entirely handled by personnel with direct hands-on field experience with PTC and track maintenance.

3.1 Interview Respondents

The 41 railroads and entities were broken down into 3 major groups, as listed in Table 1, which also details the number of responses. A few respondents indicated they had not fully implemented PTC, so were unable to provide responses. Others indicated they did not directly implement PTC, as they exclusively operate on tracks maintained by, and in some cases, operated by, host railroads. Where non-railroad contractors perform the operations and maintenance, very few responded. One that did return contact indicated that their confidentiality agreement with the primary agency prevents any such outside communication; TTCI was unable to contact anyone with those parent agencies.

Table 1. Interview Responses

Railroad/Entity Type	Total Number	Responses	Percent Responses
Class I	7	5	71%
Commuter	26	12[5]	46%
Other	8	7	88%
Total:	**41**	**24**	**56%**

[5] Of the 26 commuter railroads, 2 responded and indicated they operate on a host railroad and have no direct wayside maintenance responsibilities. TTCI research indicates that an additional three non-responding railroads operate on host railroads and six are operated by contractors.

The general uniformity in many of the responses increases confidence in the results of this analysis. In many cases, responding railroads indicated similar experiences and points of emphasis.

3.2 Interview Questions and Topics

The following formal interview questions were used in the interviews and were initially developed internally by TTCI and modified with input from FRA:

- How are PTC critical asset lists generated?
- How are changes to the PTC critical asset list handled?
- Do maintenance personnel use the PTC asset list for maintenance purposes?
- What efficiencies/inefficiencies have MOW forces experienced due to the implementation of PTC? (Is track access easier, harder, or any different?)
- Have MOW rule changes been required with the implementation of PTC? Are MOW job duties different or have any new requirements?
- Is large MOW equipment (rail-grinding trains, slot trains, track renewal machines, etc.) equipped with PTC?
- Have any additional secondary protection devices, for MOW personnel, been implemented (with or separately from PTC)?
- Have you seen any complacency by MOW personnel because of PTC? (Do MOW personnel have a false sense of security because of PTC?)
- Any other issues related to PTC?

3.3 Summary of Responses

A summary of the interview responses to each respective lines of questioning follows in the sections below.

3.3.1 How Are/Were PTC Critical Asset Lists Generated?

There was a range of responses to this question. Common responses can be grouped into the following:

- Critical asset list generated (from scratch) by PTC installation contractor and/or design consultant.
- Critical asset list generated by PTC installation contractor and/or design consultant starting with existing railroad asset lists (primarily mapping with precision coordinates) and independent validation of critical assets.
- Critical asset list generated by railroad with assistance from consultants (surveyors/administrative). The effort was led by the railroad.
- Critical asset list completely generated by railroad using railroad personnel.

TTCI considered this question important, as a lead into other questions related to critical assets. Investigators felt that if an organization was actively involved in the generation of the critical asset database, it would be better equipped to manage future changes. The various railroads and entities are dealing with critical asset database management using a similar mix of strategies, but not necessarily the same strategy as used in the initial development.

Upon reviewing the interview responses, there are two major factors that impact the complexity of critical asset database management, regardless of how the original critical asset database was generated:

1. Number of critical assets
2. Interoperability requirements where multiple railroads interface.

Both items are related to the workload required to maintain PTC. These are overhead resource issues that are independent of the number of trains being operated. The same level of work is required regardless of traffic and cannot be downsized with economic downturns. While the workload may be reduced because of reduced capital expenditures, there will always be a base level of administrative work required to maintain the critical asset databases.

3.3.2 How Are Changes to the PTC Critical Asset List Handled?

In every case, the responding railroad has implemented a change management process that typically includes a structured group of internal PTC stakeholders, including the Critical Database Manager, and signal, communication, transportation, and engineering (MOW) personnel. All respondents indicated that the PTC critical asset list change processes include regular communication and/or meetings to discuss planned and upcoming MOW work and its effect on critical asset relocations. An example of major planned maintenance might be the installation of a new switch or the addition of a new siding. Some railroads indicated that their change process makes formal allowances for urgent or unplanned changes (e.g., derailment cleanup or other rapid track maintenance). Those who indicated that they had the most sophisticated process for unplanned/urgent events were larger railroads with dedicated staff to perform rapid surveys to update and validate critical asset locations. Others, particularly smaller organizations, indicated they did not foresee a need for a separate urgent/emergency maintenance process, as they could quickly communicate to stakeholders (generally a smaller group of people on smaller railroads) if urgent maintenance that might involve critical asset relocation was necessary.

Answers varied widely by respondents. One railroad indicated that it has adopted a 24/7/365 telephone-initiated process to provide immediate support for field personnel that may be making critical asset location changes. Another railroad uses a paper form if work results in a critical asset move. A Class I railroad reported that a 30-day review process was implemented to request, review, and approve potential critical asset movements due to maintenance activities. That same railroad reported having a process in place to allow for emergency updates as well. Another Class I railroad has trained its MOW workers to report any potential critical asset relocation in its work reporting system. This report triggers a review by the PTC critical asset stakeholders managing the critical asset database.

Responses to this question indicated that separate surveying crews (outside of MOW departments), tasked with conducting critical asset locationing and auditing, are ultimately notified to complete the survey. Engineering or MOW surveying crews do not appear to be used for this purpose.

Responses indicated that critical asset locations in the track database must be verified within 2.2 meters of their actual location. To achieve this, individual railroads may elect to resurvey a critical asset any time it is moved.

Freight railroads often operate over other railroads' track. The management of critical assets on one railroad affects the PTC systems of other railroads. In general, railroads operating the same type of PTC (e.g., freight railroads using ITC PTC) can communicate asset database updates and automatically download updated database files. During information-gathering, TTCI discovered a unique situation in which a Northeast passenger railroad, operating a different form of PTC, is required to notify freight railroads (using ITC PTC) that operate on its track if a critical asset location changes greater than 6 inches.

While there appear to be different ways in which asset location changes are being communicated, resurveyed, and input into an updated database, the commonality in all responses is the recognition of the importance of such a process. There is a strong emphasis in ensuring that critical assets are properly located. This appears to be especially true for smaller, more easily moved critical assets such as the operational signs in Figure 4. For MOW departments, the role they play is in communicating where and when these changes occur.

Most respondents indicated an increased level of communication between communications and track engineering departments due to the increased attention being paid to PTC critical assets.

3.3.3 Do Maintenance Personnel Use the PTC Asset List for Maintenance Purposes?

Most responses indicated that that the active PTC critical asset database was "firewalled" from their maintenance databases because of the safety-critical nature of this database. In some cases, PTC asset databases are accessible by maintenance personnel of through corporate intranets in a "read only" format.

Many respondents indicated that exiting MOW asset information and locations formed the basis for development of their PTC critical asset databases. In general, MOW departments appear to be taking advantage of the precision mapping and more frequent field validation of asset locations to update their maintenance databases. Overall, a culture focused on the accurate location of tracked assets seems to have developed, in part, due to the implementation of PTC.

Maintenance asset databases, while having some overlap with PTC critical asset databases, contain far more information than the PTC databases. Maintenance databases do not have a direct effect on the operation of trains. Railroads maintain extensive databases related to rail, ties, bridges, signal communication systems, road crossings, as well as their health, inspection status, and condition. This level of information is not needed for PTC, but for railroads with less experience in asset management, the availability of critical asset databases appears to be helpful.

3.3.4 What Efficiencies or Inefficiencies Have MOW Forces Experienced Due to the Implementation of PTC? Is Acquiring Track Access Easier, Harder, or Any Different?

The responses to these questions were fairly uniform. Nearly all respondents indicated that access to the track is virtually the same as it was prior to PTC implementation. Some respondents indicated some delays in obtaining track access, but only during the initial startup and debugging inherent with bringing PTC on board, and that the situation quickly improved.

Startup issues included:

- Slower responses from dispatchers as PTC was rolled out by individual railroads.
- Delays caused by slow trains due to train crews learning PTC or initial debugging of the PTC system itself.
- All indicated that these were fail-safe type issues that slowed trains and were not critical safety failures.

Two respondents indicated some minor ongoing inefficiencies. One respondent's system includes a large number of balises.[6] These devices have limited the ability to temporarily store metal materials along the track in preparation for, and after the completion of, maintenance activities due to the potential for electrical interference. The respondent indicated that this was not something that will have significant impacts on maintenance, but it requires changing long established maintenance practices and additional training for personnel. A second respondent (whose PTC implementation strategy was design-build-operate-maintain) indicated that the PTC service provider insists that they must pre-survey and post-survey the track as a part of any track surfacing and alignment work, including both spot and out-of-face work. This does not appear to be the case on other railroads.

Some railroads indicated that the communications backbone that had to be installed as a part of PTC has allowed some increased efficiencies, such as improved dispatcher/MOW communications and the ability to push non-vital train location information to personnel in the field (used for short-term planning, not protection).

One railroad indicated some start-up issues related to MP signs not being exactly 5,280 feet apart. This is not a PTC system issue, since all MP sign locations were accurately mapped, but an issue for MOW field personnel in determining the correct location for temporary speed restriction signs and red/yellow board protection at fractional MP locations (between the physical MP signs).[7] Dealing with the non-uniform distances between MP signs is an issue common to all railroads. While the physical location of the MP signs is not a significant issue, how to determine the exact location of fractional MP locations between the signs is. One railroad indicated in the interview that it was initially dealing with this issue by requiring all temporary signage be

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[6] A balise is a transponder mounted in the track that transmits information to trains as they pass over the device.

[7] This issue is not unique to a single railroad. MP signs that are exactly 5,280 feet apart are more an exception rather than the norm for a wide variety of reasons, such as alignment changes, track relocations, and mergers of different railroads over time. The distances between MP signs have been observed to range from less than 1,400 feet to many miles. MP signs are considered a location indication marker, and not an accurate marking of the exact accumulated footage or mileage from an arbitrary start location.

extended to the nearest known critical asset location that can be visually verified in the field by MOW personnel (e.g., signal, switches, MP signs, road crossings, etc.). As a more permanent solution, it was adding permanent markers in the field at the intervening 1/10 mile intervals, between the MP signs. Another railroad was adding additional functionality to critical asset "nodes" (intermediate locations) that facilitated their use for enforcing speed restrictions and MOW protection.

Related to this issue, one freight railroad indicated that, under PTC, track protection limits must be extended out so they can be defined by known critical asset locations, easily identifiable in the field. In the past, if work was being conducted at MP 23.5, an Employee-in-Charge (EIC) could request track protection generally from arbitrary locations (e.g., MP 23.2 to MP 23.7). The procedures on this railroad now require each end of the protection to be a known critical asset location (i.e., the switch at MP 23.21 to the signal at MP 23.95). This is not a limitation imposed by the regulation of PTC, but rather a practice implemented by this railroad to reduce the risk of errors by field personnel in locating temporary work and speed restriction limits. As this example demonstrates, PTC is not implemented identically on all railroads.

All else being equal, PTC should not have any influence (either positive or negative) on the acquisition of track protection or the duration of time available for track maintenance. As PTC is a transparent overlay system that only enforces the authority otherwise given to the train, track maintenance windows and track availability remain the same.

Some railroads did report that track access was more difficult during their PTC rollout, due to train delays or competing needs to access a section of track. Start-up issues should be expected with any new system, particularly with one as complex as PTC. No railroads indicated issues related to critical safety failures. The authors expect that the railroad industry will continue to improve efficiencies as more experience is gained. As PTC continues to be implemented and utilized, they expect no effect on track maintenance windows.

3.3.5 Have MOW Rules or Job Responsibilities Changed with the Implementation of PTC?

The responses to this line of questioning were very uniform. Respondents indicated that PTC had not caused any MOW rule changes and that MOW worker responsibilities, in large part, had not changed as a result of PTC. The lack of MOW rule changes did not come as a surprise. For MOW workers, PTC is a transparent overlay system. Some respondents indicated that MOW work prior to and after PTC implementation is identical. They continue to go about their work with the same procedures and with the same methods of track protection as before.

While not part of formal MOW rules, all railroads have implemented processes and procedures relating to changes to critical assets because of the implementation of PTC (See Section 3.3.2). Some railroads reported training implemented for MOW workers on these processes and procedures.

3.3.6 How Are MOW Trains (e.g., Ballast Trains, Rail Trains) and Other Pieces of MOW Equipment (Rail Grinders, Tampers, Tie Gang Equipment, etc.) Treated in Regard to PTC?

Subpart I of the PTC Systems regulation 49 CFR Part 236 has broad definitions of "locomotive" and "train." Results from interviews and discussions with TTCI PTC experts and railroad representatives has shed further light as to how PTC applies to MOW trains and equipment in practice.

Every respondent indicated that individual pieces of MOW equipment (e.g., tampers, rail grinders, tie inserters, spikers, etc.) are not equipped with PTC, even if they are moved in a train with other MOW equipment. Moves of this type of MOW equipment are handled as they were prior to PTC.

Where MOW cars (e.g., railcars, ballast cars, or tie cars) are moved in a train, the train is pulled by a PTC-equipped locomotive if required. For example, a rail train would travel over a railroad to the work location as a regular PTC-equipped train, operated by regular train crews. Once at its work location, however, typical MOW protection (e.g., exclusive track occupancy) would then be used while the rail is physically being unloaded. While in "work" mode, the train is not using PTC.

Only one respondent indicated that "PTC-like" equipment might be installed on MOW equipment. This one respondent, a high-traffic-density railroad, indicated it was considering investigating the feasibility of equipping on-track equipment (including hi-rail vehicles) with a PTC-like system. Section 6 discusses this type of technology.

3.3.7 Have Secondary Warning Systems for MOW Personnel Been Implemented (With or Separately from PTC)?

Secondary warning systems, in this context, are systems designed to alert a roadway worker or work group of the presence of an approaching train. Systems can include wearable arm bands, other devices, or boxes placed near the center of the work crew. These are independent systems that are not interconnected to PTC in any way. In general, it appears these systems are still being studied and tested by interested railroads.

While some railroads have implemented or have tested secondary warning systems, they were implemented either before and/or completely apart from PTC. These types of technologies are discussed in the future opportunities section below.

3.3.8 Have You Seen Any Complacency by MOW Personnel Because of PTC? (Do MOW Personnel Have a False Sense of Security Because of PTC?)

The answers to this line of questioning were very uniform. No respondent indicated any sense of complacency or false sense of security surrounding what PTC is doing (and what it is not doing) for the MOW worker. Most of the respondents indicated that during conventional RWP training they are reinforcing that while PTC provides enforcement of train authority, the fundamental principle to expect a train *in any direction, on any track, and at any time* does not change with PTC. In fact, this principle forms the foundation of RWP practices around the world.

One of the authors attended a recent MOW PTC training class and the firm message included in the training was "act like PTC does not exist…a MOW person wayside does not know if PTC is active or inactive or if operable on a particular train." Additionally, the training included reinforcement that PTC does nothing for "lone worker" or "watchman/lookout" forms of track protection. In general, responses to this question indicated a strong focus on avoiding any sense of complacency or confusion about what PTC does for MOW workers.

4. Effects on Roadway Worker Protection

MOW workers' primary safety goal is to protect themselves from conflicting train movements. Secondarily, they also must protect trains from entering tracks made unsafe for passage while undergoing repairs. Such procedures are referred to as Roadway Worker Protection (RWP). To aid readers of this report, Appendix B contains information about common methods to provide RWP.

PTC, as an overlay system, is transparent in nature to a roadway worker. A roadway worker, while conducting his/her work, will not necessarily be aware of PTC or interact with the PTC system in any way. A Roadway Worker-In-Charge (RWIC – the single and primary point of contact in each work group with sole responsibility for the protection of that group) interacts with the train dispatcher, not directly with the PTC system. PTC enforces the authority given to a train through the otherwise established train control system. This is an important concept in understanding of what effect PTC may have, and more importantly what effect it does not have, on track maintenance and RWP scenarios.

To consider what effect PTC has on RWP, one must consider the types of RWP used in the industry. There are many types of RWP allowed for under FRA 214 regulations. The extent of the effect of PTC on each type of RWP is presented in Appendix B. However, for the purposes of this report, the effect of PTC on RWP can generally be summarized in the following two categories: A and B:

A. If the train control system would otherwise be aware of the presence of a roadway worker fouling the track, PTC will enforce a train from entering that work zone.

In situations covered under A, the dispatcher and train control system are made aware of the presence of a roadway worker through previously established rules. For example, in a MOW situation where exclusive track occupancy is arranged, PTC enforces that exclusive track occupancy by preventing a train from encroaching into the work zone. This is because the form of protection (exclusive track occupancy) requires notification of the dispatcher to grant authority for the work zone to be occupied by the roadway worker(s), and the roadway worker in charge is given authority of the track within the working limits. The same would be true for a foul time RWP situation because the dispatcher withholds the authority of trains or other equipment to move into or within the foul time limits. In each of these examples, PTC would enforce the authority otherwise given to the train. That would mean enforcing a stop if the train was predicted to encroach into the track upon which it does not have authority to move.

B. If the train control system wouldn't otherwise know the presence of a roadway worker fouling the track, PTC will not enforce a stop.

In situations covered under B, the train control system/dispatcher is not aware of the presence of a roadway worker. Two common examples of such situations are watchmen/lookout protection (train approach warning (TAW)), or lone worker situations (independent train detection (IDT)). The PTC system is not aware of the presence (or lack thereof) of roadway workers, because in these cases, roadway workers provide their own protection. In these situations, the train has the authority to move over the track and it is the responsibility the roadway worker to clear the fouling limits of the track. PTC does not protect an inattentive lone worker from being struck by a train or MOW workers whose watchman/lookout(s) fail to provide adequate warning. TAW and lone worker protection are utilized for a variety of MOW activities and are advantageous from a train operations perspective. These forms of protection remain an important and safe way of working but are not made any safer than they otherwise would be with the overlay of PTC.

PTC does nothing to prevent human factor-related RWP failures by MOW workers. While it does provide additional protection to MOW workers from certain types of human factor failures by those controlling and operating trains (e.g., unintended encroachment into a section of track occupied by a MOW crew), it does so only under certain defined circumstances, based on the type of protection being used. PTC does nothing to prevent or provide protection for a MOW worker for accessing a track or exceeding its limits (as PTC does with a train). Even in PTC territories, if IDT/lone worker or watchman/lookout protection is being used, PTC is blind to these types of protection and cannot intervene to prevent conflicts. MOW work in slow-speed yard or terminal areas is not covered since PTC is not required in these areas. This should not be taken as critical commentary of PTC. Where installed, it does everything it was intended to do, and it will significantly improve the safety of certain MOW scenarios; however, as the intent of the report is to document the effects of PTC on track maintenance, it is important to point out the track maintenance scenarios where safety is not inherently improved by PTC.

For MOW workers, track access today is not inherently different than before the implementation of PTC. The methods of RWP and related rules that apply to MOW forces are the same as they were before.

4.1 Computer Dispatching Systems

There was some confusion from respondents regarding computer-aided dispatching (CAD) systems, including those that allow roadway workers to view the locations of trains, communicate with the dispatcher, and request track protection through the software. In some cases, these systems were implemented in parallel with or immediately preceding PTC. To some, this is taken that CAD is PTC, and not just a component that works along with PTC. Recently, these systems have been observed on roadway worker laptops/tablets (e.g., in their vehicles). To be clear, these types of systems are not PTC. They represent improved technology for the roadway worker to communicate with the dispatcher and make available more data for them to conduct their jobs (e.g., easily see other work crews and the location and direction of trains in the territory, etc.), but the rules and basic principles of RWP are not affected by these new systems, and these new systems do not imply a communication link between MOW crews and PTC. CAD systems and potential implications on MOW workers is discussed in Section 6.

4.2 Human Factors-Related Issues for Track Maintenance Workers

PTC is designed to reduce the effect of human factor errors related to train movement. However, the topic of human factors at play in the PTC era also applies to roadway workers. There are two specific human factors considerations that should be documented based on the work conducted in this project:

1. The need to avoid the risk for false assumptions on what PTC is (and what it is not) doing and the potential for a false sense of complacency. While no railroad reported such complacencies or misunderstandings, RWP training should continue to reinforce that PTC is simply enforcing train authority and that the basic principles of RWP do not change as a result of PTC.

2. Most importantly, if bad information is given to PTC, the system will enforce the information input into it. For example, if a human factors-related error results in improper locationing of a critical asset (e.g., failure to report a move), incorrect working limits, or other data being fed to PTC, the system will only enforce the information provided to it. As previously mentioned, railroads have processes to both verify the accuracy of track databases and audit the track databases to mitigate this potential human factor error.

4.3 Effect on RWP Training

49 CFR Part 236 – Rules, Standards, and Instructions Governing the Installation, Inspection, Maintenance, and Repair of Signal and Train Control Systems, Devices, and Appliances Subpart I, "Positive Train Control Systems" of the PTC regulation, deals with the training requirements for PTC. In particular, Section 236.1049 discusses training specific to roadway workers (CFR, 2010):

> *(a) Roadway worker training. Training required under this subpart for a roadway worker shall be integrated into the program of instruction required under part 214, subpart C of this chapter ("Roadway Worker Protection"), consistent with task analysis requirements of § 236.1043. This training shall provide instruction for roadway workers who provide protection for themselves or roadway work groups.*
>
> *(b) Training subject areas.*
>
> > *(1) Instruction for roadway workers shall ensure an understanding of the role of processor-based signal and train control equipment in establishing protection for roadway workers and their equipment.*
> >
> > *(2) Instruction for all roadway workers working in territories where PTC is required under this subpart shall ensure recognition of processor-based signal and train control equipment on the wayside and an understanding of how to avoid interference with its proper functioning.*
> >
> > *(3) Instructions concerning the recognition of system failures and the provision of alternative methods of on-track safety in case the train control system fails, including periodic practical exercises or simulations and operational testing under part 217 of this chapter to ensure the continued capability of roadway workers to be free from the danger of being struck by a moving train or other on-track equipment.*

The implications of PTC on roadway worker training, and any changes that have been made, was discussed during the interview and information-gathering stage of this project from various railroads' perspectives. No railroad reported significant changes to their RWP training. An emphasis in training on expecting a train at any time, in any direction, and at any speed, was a common response.

5. Conclusion

The tools and systems in place to effectively conduct track maintenance have not been affected by PTC. However, the findings from this study are important: to document the effects that PTC has had on track maintenance and to avoid any confusion on the MOW side of the industry about PTC. Key findings and conclusions from this study include:

- The largest and most significant effect that PTC has had on track maintenance has been the need to manage and communicate changes to PTC critical assets during typical MOW work. Many of the PTC critical assets are managed by MOW departments. When an asset location is changed, it must be reported and resurveyed to update the PTC critical asset database.
- All respondents reported having in place a change management process to handle changes in location to PTC critical assets. There appear to be various reporting systems and approaches to managing critical asset location changes, depending on the size of the railroad and the number of critical assets controlled.
- In general, there was an emphasis on the change management process of critical assets that are more easily relocated in the field (e.g., MP signs, yard limit signs, or block limit signs).
- No changes to RWP practices were reported as a result of PTC. Other than the key impact of PTC enforcing a stop and preventing the incursion of a train into an established work zone (e.g. exclusively occupied track), PTC has no other impact on RWP and is transparent to MOW workers.
- The basic principles of roadway worker protection – *to expect a train in any direction, on any track, and at any time* – have not changed. RWP protection situations that are not known to the train control system, such as watchman lookout protection or lone worker protection, are unaffected by PTC
- It is important to recognize the need for roadway workers to avoid any sense of complacency or a false sense of security under PTC. Knowing what PTC does, but more importantly, what it does not do for a roadway worker is paramount.
- While some railroads did report recent difficulty accessing track for track maintenance, these issues were directly related to the rollout and debugging of PTC causing train delays. PTC, as being implemented, should not inherently have any impacts on track access, availability, or duration to perform maintenance.
- There were no reports of MOW rule changes implemented as a result of PTC. Many respondents indicated an emphasis on the importance of reporting critical asset locations changes as necessary.
- PTC has not had any impact on MOW trains or MOW equipment. Large MOW trains are still operated under similar protection as before PTC. MOW equipment is not equipped with PTC; however, some railroads reported interest in PTC-like systems for hi-rail trucks and MOW equipment. Such systems provide an alarm/alert for MOW vehicles reaching the limits of their authority and are not tied into the throttle or braking systems of the vehicle.

6. MOW Safety – Opportunities and Emerging Technologies

The PTC era has brought about technologies and opportunities that could improve the safety of common track maintenance responsibilities. PTC regulations established the minimum, basic requirements of PTC. However, emerging technologies have opened the door to improve other aspects of track maintenance and roadway worker protection outside the purview of PTC regulations. Some of these technologies are intended to be integrated with PTC, while others are standalone, separate systems. The emerging technologies discussed in this section, it should be understood, are not PTC and are not required by PTC regulations.

6.1 Computer-Aided Dispatching and Related Software

The presence of CAD systems and related software have begun to influence MOW personnel. Three specific topics were discovered as part of this study.

6.1.1 Electronic Communications of Track Requests and Authority

Some railroads have systems in places that allow MOW personnel to securely communicate with the dispatcher for track access requests, speed restrictions, and to receive confirmations of such authorities. Once the authority is approved by the dispatcher, the authority is automatically transmitted to the requestor. In some systems, requests are implemented using a diagrammatic map interface to aid in selection and to prevent entry errors.

6.1.2 Secure Code for Releasing Track Protection

One responding railroad has implemented a system where, when track access authority is granted, the EIC is sent a "secret code" that only the EIC can see. The code, generated by the CAD system, is securely hidden from the dispatcher. Without this code, a dispatcher cannot remove the protections in place for that EIC until the EIC releases the authority and provides that code to the dispatcher; the dispatcher then enters the code in to the CAD system, which will only then allow the work area protection to be removed. This procedure is independent of PTC.

6.1.3 Train Location Information

Some railroads have the developed the ability to "push" electronic dispatcher displays out to personnel in the field. This is typically done using secure web-based communications. This has been observed to be an excellent efficiency tool, where MOW personnel can easily see where trains are, where others hold track authority, and visually observe the track authority granted to them. In some cases, these systems allow zooming in to the track circuit level of resolution. This provides an excellent tool for planning and has improved the efficiency of those with access and reduced unnecessary dispatcher workloads. The viewing of electronic dispatcher displays by MOW personnel are used as information only and are not a replacement for required protection.

6.2 Secondary Warning Systems

Secondary warning systems have existed prior to PTC. Automated train approach warning is not new, and it has been implemented by some railroads in the past, including systems that use automated warning lights/horns, which are tied into the train control system, and that provide advance warning of approaching trains. Some of these systems could indicate the individual track on which the train is approaching.

These systems have become more commercially available; they are coincidental to PTC but are not a part of PTC. They are standalone systems. A wide variety of secondary warning systems exist for MOW, including[8] CERTIS™, EMTRAC™, Protran™, RWPS™, and ZoneGuard™. These MOW safety enhancement systems include train approach secondary warning, MOW/train conflict prevention, MOW equipment collision avoidance systems, MOW worker/equipment conflict prevention/warning systems, and warning systems for MOW workers in electric traction power environments (electric third rail or electric overhead catenary).

6.3 Critical Alerts

Critical alerts such as those for hot rail temperatures, high winds, earthquakes, flash flooding, or other severe weather could be integrated with PTC. This concept could be viewed as a warning automatically pushed out to trains and, if required, automatically command restrictions to specific trains or to all trains within an area (e.g., subdivision, area, or region). The delivery and confirmation of these alerts could be electronic and faster than the more manual practices currently used. Such technologies already exist and are being used by railroads. An example is the earthquake warning system used on high-speed rail lines in Japan (Nakamura & Tucker, 1988; Yamamoto & Tomori, 2013).

6.4 Asset Databases

As discussed in Section 3, asset databases developed for PTC may offer opportunities to railroad track and track maintenance departments. More accurate information on curvature, track centerlines, special trackwork locations, etc., may be used to improve track maintenance, track design and construction, and track asset management practices – particularly for railroads with less experience in asset management. As discussed, some maintenance personnel reported having ready access to these databases and are using the information to benefit maintenance activities. Generally, PTC appears to have promoted a culture where asset locations are more accurately tracked and documented.

6.5 Track Monitoring System Integration with PTC

The authors are aware of systems being developed to facilitate track performance monitoring systems integration with PTC. Some of these systems could be integrated with PTC to communicate accurate locations of track defects, broken rails, or rail flaws to PTC in real time to stop approaching trains or communicate temporary speed restrictions. Such track monitoring systems could, for example, be mounted on a locomotive at the trailing end of a train with distributed power. Alternative systems currently being developed use advanced track circuit designs or fiber optic acoustic detection to improve the location accuracy of rail flaw detection.

As the rails are part of the traditional block signaling circuit (often referred to as the track circuit), rail breaks are typically detected through an interruption in a track circuit's signal, but only for certain types of rail breaks. Conventional track circuits do not identify a rail break's specific locations within a block. Thus, the location of a break has a typical uncertainty on the order of 2 miles. If moving block operation (Dick, Mussanov, Evans, Roscoe, & Chan, 2019) or

[8] TTCI nor FRA endorses these or any other specific commercial products. These are presented here only as examples for readers of this report, not endorse these specific products or impugn those not specifically listed.

quasi-moving block operation, facilitated by PTC, are implemented in the future, improved methods of detecting rail breaks, and perhaps detecting rail flaws that occur before the rail actually breaks, will be necessary. Moving block operation requires much more accurate real-time location of rail breaks. Rail breaks (and flaws), when detected, could be communicated to the PTC system with a measured location and recommended restrictions based on the severity of the defect found. This same concept could be expanded to also include coordination with track geometry measuring systems and vision inspection systems, where the location of critical defects could potentially be immediately and automatically communicated to the PTC system.

6.6 Employee-in-Charge Portable Remote Terminal

Employee-in-Charge Portable Remote Terminal (EIC-PRT) (FRA, 2016) is a system that allows an EIC (MOW worker) to grant electronic permission for train operation into and through an EIC-controlled section of track, to set the speed limit through that section that PTC will enforce, and to impose temporary slow orders. The EIC does so using a portable device that is carried, allowing communication to the locomotive onboard system. EIC-PRT is designed to integrate into existing PTC systems by taking advantage of the infrastructure already in place for PTC. Today, without EIC-PRT, PTC prevents train entry/movement in a work zone (e.g., under a Form B Track Bulletin[9]) until the locomotive engineer has confirmed that EIC permission has been verbally granted to enter the limits or to resume movement within the work zone. When the locomotive engineer acknowledges that EIC instructions have been received (e.g., over the radio), the onboard PTC system assumes the train has permission to enter/move in the work zone and that the train crew will adhere to the speed restrictions imposed by the EIC, even if more permissive speeds are allowed by the onboard. This current approach is susceptible to human error by providing an opportunity for the train crew to incorrectly respond to the onboard prompt and enter the work zone without EIC permission or knowledge, prior to roadway workers being clear of the track and in safe locations per railroad operating rules and 49 CFR 214 requirements. This issue is now being addressed by the addition of the EIC PRT segment to the ITC architecture.

EIC-PRT has no effect on coordinating/acquiring roadway worker protection for the EIC and the work group. EIC-PRT is simply a newer technology to improve safety by facilitating direct communication and coordination between the EIC and PTC-equipped trains.

6.7 PTC-Like System for MOW Equipment, Including Hi-Rail Trucks

Track maintenance activities often necessitate the use of MOW and contractor-operated hi-rail vehicles, including large and small rail-bound MOW equipment. While the PTC regulation does not include such MOW vehicles, future systems could deploy PTC-like technology for MOW vehicles. The use of PTC technology for MOW equipment could provide protection to help prevent, for example, hi-rail vehicles from moving outside of their authority (i.e., operating through switches, into and out of sidings, on and off of grade crossings, etc.) and to notify

[9] This type of protection is also known as: Form B, Form Y, Form D, Form W, Rule 42, depending upon the system of Rules used. With this type of protection, demarcated by advance and limit warning signs, an EIC is granted authority of a section of track, and each train passing through that area may only do so with the permission and under the direction of that EIC.

approaching trains to react to these incursions, or prevent overspeed events by communicating with the PTC infrastructure already in place.

However, this concept, while conceptually simple, would be a major technical challenge. Most MOW vehicles do not look and act like a train. They do not necessarily shunt the track or interact with the underlying train control systems the same way as a train, creating significant technical challenges. Further, interconnecting the onboard PTC system with the throttle and brakes of MOW equipment and hi-rail trucks (similar to what is done for PTC-equipped locomotives) represents a significant technical challenge. It is likely that PTC-like systems implemented into MOW equipment or hi-rail trucks would be an alert/alarm type system not necessarily directly enforcing the authority of the vehicle.

6.8 Enhanced Use of Global Positioning Systems

Some railroads have provided their MOW field staff with accurate GPS location mapping systems, which detail critical assets and fractional MP locations (with as much resolution as $1/100^{th}$ mile). MOW personnel can use these systems to locate themselves in the field, to access locations more efficiently in the field, and to properly identify and communicate intermediate locations to dispatchers. To deal with the common inaccuracies in determining GPS positions, these are overlaid on maps that provide field workers with visual references in the field to validate their locations, separate from GPS signals. Some of these systems provide an active scrolling display of engineering track charts, recent track geometry data, and aerial mapping to display relevant information to MOW field workers regarding their current location. Such systems are not integrated with PTC.

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Appendix A. List of PTC Railroads

This table lists candidate railroads that TTCI enlisted to provide answers to the questionnaire. This list was generated from the FRA/DOT – PTC Implementation Status by Railroad Report (FRA, 2018).

PTC Railroads			
Class I Railroads			
Item	**AAR Reporting Mark**	**Name**	**Region Served** ***(related to FRA PTC Requirements)***
1	BNSF	BNSF Railway	Western US
2	CN	Canadian National Railway	Central US
3	CP	Canadian Pacific Railway	Central US
4	CSX	CSX Transportation	Eastern US
5	KCS	Kansas City Southern Railway	Mid-South US
6	NS	Norfolk Southern Railway	Eastern US
7	UP	Union Pacific Railroad	Western US
Commuter Railroads			
Item	**AAR Reporting Mark**	**Name**	**Region Served** ***(related to FRA PTC Requirements)***
8	ACEX	Altamont Corridor Express (ACE)	San Jose, CA/Stockton, CA
9	CMTY	Capital Metropolitan Transportation Authority ("Metro")	Austin, TX
10	CFRC	Central Florida Rail Corridor ("SunRail")	Orlando, FL
11	CDOT	Connecticut Department of Transportation	Eastern CT
12	DCT	Denton County Transportation Authority	Denton, TX (Suburb of Dallas/Ft Worth, TX
13	UFRC	FrontRunner Commuter Train ("UTA")	Salt Lake City, UT
14	LI	Long Island Railroad	New York City/Long Island, NY
15	MACZ	Maryland Area Regional Commuter (MARC)	Washington, DC/Baltimore, MD
16	MBTA	Massachusetts Bay Transportation Authority	Boston, MA

PTC Railroads			
Commuter Railroads			
17	NJTR	New Jersey Transit (NJT)	New York, NY/Northern NJ
18	NMRX	New Mexico Rail Runner Express ("Rio Metro")	Albuquerque, NM
19	MNCW	Metro-North Commuter Railroad	New York City, SW CT
20	SDNX	North County Transit District (NCTD)	San Diego, CA
21	NIRC	Northeast Illinois Regional Corporation ("METRA")	Chicago, IL
22	NICD	Northern Indiana Commuter Transportation District ("South Shore Line")	Chicago, IL/NE Indiana
23	NSCR	NorthStar Commuter Rail	Minneapolis, MN
24	JPBX	Peninsula Corridor Joint Powers Board ("CalTrain")	San Francisco/San Jose, CA
25	PATH	Port Authority of New York and New Jersey	New York, NY/Newark, NJ
26	RTDC	Regional Transportation District Commuter (RTD)	Denver, CO
27		Sonoma-Marin Area Rail Transit (SMART)	San Francisco, CA (North Bay)
28	SCR	Sound Transit	Seattle, WA
29	SFRV	South Florida Regional Transit Authority ("TRI-RAIL")	Miami/West Palm Beach, FL
30	SPAX	Southeastern Pennsylvania Transportation Authority ("SEPTA")	Philadelphia, PA
31	SCAX	Southern California Regional Rail Authority ("Metrolink")	Los Angeles, CA
32	TRE	Trinity Railway Express	Dallas, TX
33	VREX	Virginia Railway Express (VRE)	Washington DC/NW Virginia
Other Railroads			
Item	**AAR Reporting Mark**	**Name**	**Region Served** ***(related to FRA PTC Requirements)***
34	ARR	Alaska Railroad	Alaska

PTC Railroads			
Other Railroads			
35	ATK	Amtrak	Nation Wide
36	BRC	Belt Railway Company of Chicago	Chicago, IL
37	CRCX	Conrail Shared Assets Operations (aka CASO – jointly owned by NS/CSX)	Eastern US
38	FECR	Florida East Coast Railway (Portions include Brightline/Virgin Trains Operations)	Western Florida
39	KCT	Kansas City Terminal Railway	Kansas City, MO

Appendix B. Roadway Worker Protection Overview and Effect of PTC

This appendix is intended as a high-level overview of RWP as defined by FRA regulations related to RWP requirements. The examples and explanations of the various forms of RWP are not intended as a comprehensive training for personnel to protect themselves from train movements, but to provide sufficient background and understanding to those readers not familiar with all of the various principals of RWP to understand the terminology used in this report and how they relate to PTC. The detailed requirements for RWP can be found in the 49 CFR Subtitle B, Chapter II, Part 214, Subpart C – Roadway Worker Protection (CFR, 1996).

B1. Purpose of RWP

The purpose of RWP according to 49 CFR §214.301(a) is to prevent accidents and casualties caused by moving railroad cars, locomotives or roadway maintenance machines striking roadway workers or roadway maintenance machines (CFR, 1996). In short, it is the processes used to protect people performing work on the track from trains and to protect trains from that work. In the U.S., FRA defines how such protection is provided. However, while the terminology used may differ, these basic principles apply to any railroad in the world, based on the physics of railroads and the various events that can occur.

To further enhance the safety of RWP, everyone operating on a railroad, from train crews to a laborers and contractors, are trained on how it works before they go out onto the tracks; they are re-trained annually, and are monitored and tested on their performance in the field. Additionally, the maintenance workers involved in setting up protection for the RWIC, also known as the EIC, receive additional training, and must be fully qualified on the rules and physical characteristics for that segment of the railroad. Further, to prevent miscommunication, only a single person can oversee the protections used for any roadway work group.

B2. Fouling the Track

Fouling the track is defined in 49 CFR §214.7 as being "within four feet of the field side of the near running rail." (CFR, 1996) Whenever a roadway worker approaches any track, it is never assumed it is safe to occupy the track until after they have verified the required protections are in place.

A key element of RWP is that all roadway workers are instructed not to foul a track unless absolutely necessary, and only do so if the required protections are in place; and never assume protections are in place. When crossing a track, only do so by first looking both ways to ensure no trains (or MOW equipment) are approaching, cross perpendicularly to the track and cross the tracks in a safe and expeditious manner. The basic rule for all railroaders is: "expect movement, at any time, on any track, in either direction." Simply put, you cannot get hit by a train unless you are in its path (Figure B1). This is constantly reinforced for those that work on railroads to combat complacency.

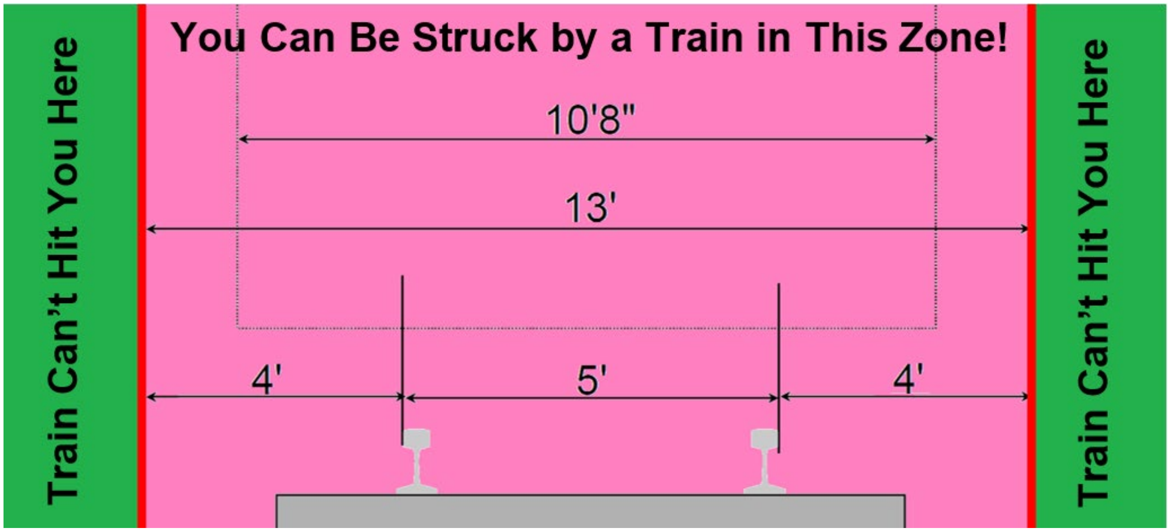

Figure B1. Fouling the Track

B3. Forms of Protection

There are various common forms of protection used for RWP in the U.S. Most have similarities, and some are nearly identical but use different terminology. In North America, three common sets of operating rules are used: General Code of Operating Rules (GCOR) (GCOR Committee, 2015) , Northeast Operating Rules Advisory Committee (NORAC) (NORAC, 2018), and Canadian Rail Operating Rules (CROR) (Transport Canada, 2020). While CROR is primarily only used in Canada, it is included here to aid those familiar with this rule set. To address the various commonly used rule sets and recognize their commonalities and to provide railroads with flexibility to determine exactly how they choose to operate their railroad, within the required regulatory limits, the various related FRA regulations provide common definitions for the various types of protection. Table B1 details the various rules, FRA requirements, and if enforcement of these various rules is provided by PTC.

Note that in most cases according to 49 CFR 214.327 "Inaccessible Track" (CFR, 1996) is not typically protected by PTC. This type of protection is commonly used in "Non-Controlled Track" and is designed to positively prevent trains from entering the track(s) where MOW are working. These track areas are not dispatched and trains are operating at slow speeds and use visual sight to prevent conflicts. Protection is provided by either installing derails, aligning switches away from the track (including Lock-Out/Tag-Out (LOTO) of those devices), or physically removing a portion of the track. However, even taking PTC into consideration, this is the highest level of protection that can be provided in the railroad industry, since it physically prevents trains from conflicting with MOW work. This type of protection is generally not feasible on Controlled Tracks, where PTC is typically installed. The protections used for Inaccessible Track would create even greater hazards to the train, since they typically would not be able to stop in time before derailing on the purposely installed obstructions used for this type of protection. Where Inaccessible Track protection is applied in high speed areas, it is supplemented with additional layers of protection that prevent trains from entering the track(s) where the protection is required.

Table B1 - Summary of FRA RWP & PTC Requirements and Common Railroad Rules[10]

Item	FRA Regulation[11]	FRA Protection Definition	Track Controlled or Non-Controlled	Enforced by PTC[12]	Example Rule Description	Example General Rules			Notes
						GCOR[13]	NORAC[14]	CROR[15]	
1	§214.321[16]	Exclusive Track Occupancy	Both	Yes	Form B, Form D (Line 5), Form Y	5.4.3	135	42/842	Protection provided using written advance notification to trains and yellow/red advance warning sights and red stop signs (Form W).
			Controlled	Yes	Track Permits, Form D (Line 4),	9.15	135	849-864[17]	
			Controlled	Yes	Track & Time, Form D (Line 4/5),	10.3	132	849-864	Typically used in CTC Signaled Territories
			Controlled	No	Block Register Territory (BRT)	6.15	N/A[18]	N/A	Typically used on light traffic lines where only one train is operated at a time, where PTC would not be typically be required. This type of protection is executed using a single sign in/sign out logbook at one location for track access authority.
			Controlled	Yes	Track Warrant Control (TWC)	14	N/A	N/A	
			Controlled	Yes	Automatic Block Signal System (ABS)	9.12.4	500	849-864 42/842 Form Y	

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10 Table only covers the types of protections specifically defined in the FRA requirements (49 CFR 214); it does not consider special circumstances where exceptions have been approved in specific situations, for specific railroads on a case-by-case basis, by the FRA, or where alternative means of safety have been implemented.

11 49 CFR 214, Subpart C - Roadway Worker Protection

12 On PTC-equipped tracks only, unless an exception has been approved by the FRA

13 General Code of Operating Rules (GCOR)

14 Northeast Operating Rules Advisory Committee (NORAC) Operating Rules

15 Canadian Rail Operating Rules (CROR). ***Note:*** *FRA PTC regulations are not applicable in Canada. These references are included only for those readers only familiar with CROR rules. Additionally, Transport Canada does not have directly equivalent rules/regulations comparable to the FRA's Part 214 – Roadway Workplace Safety.*

16 49 CFR 214.322 – Exclusive Track Occupancy, Electronic Display is not separately listed as a separate form of protections in this table. In this review it is considered as a sub-set of 49 CFR 214.321 – Exclusive Track Occupancy, with the same protections afforded, with the only change being the method of communicating the authority; approval and verification is through an electronic system, rather than verbal.

17 CROR Rules 849-864 are for TOP Track Occupancy Permit.

18 N/A does not indicate that the type rule may not be used under the that set of rules. Any railroad can supplement or modify the General Rules with their own timetable, bulletins or special instructions.

Item	FRA Regulation [11]	FRA Protection Definition	Track Controlled or Non-Controlled	Enforced by PTC[12]	Example Rule Description	Example General Rules			Notes
						GCOR[13]	NORAC[14]	CROR[15]	
			Controlled	Yes	Centralized Traffic Control (CTC)	10	N/A	849-864 42/842 Form Y	
			Controlled	Yes	Automatic Train Control (ATC)	17	N/A	N/A	
			Both	Yes	Form B, Form D (Line 5) Form Y	15.2	135	42/842 Form Y	Work Area defined by written instructions to trains and personnel and delineated on the track by yellow-red signs approaching the ends of the Work Area and red flags at the ends of the Work Area.
			Controlled	Yes	Form D Control System (DCS)	N/A	160-177	N/A	
			Both	Yes	Main Track Out of Service	N/A	N/A	101.2 Form T	
			Controlled	Yes	Siding Control Territory (SCT)	N/A	N/A	360	
			Controlled	Yes	Occupancy Control System (OCS)	N/A	N/A	801	
			Controlled	Yes	Track Occupancy Permit (TOP)	N/A	N/A	849-864	
2	§214.323	Foul Time	Controlled	Yes	Foul Time	N/A	140	N/A*	Foul time is typically exclusively used where the track is physically fouled with personnel and/or equipment, but the track (and where applicable electric catenary/third rail, or other infrastructure/equipment) is not disturbed such that it would render the track unfit for train operations. *Under GCOR/CROR no differentiation is made for the type of work covered under NORAC Rule 140. When applicable tracks are fouled, protection under other rules is required.
3	§214.325	Train Coordination	Both	Yes	Train Coordination	6.3.1	142	567, 618	Train coordination uses the trains track occupancy authority (and protection) to provide required protection for roadway workers.

Item	FRA Regulation [11]	FRA Protection Definition	Track Controlled or Non-Controlled	Enforced by PTC[12]	Example Rule Description	Example General Rules			Notes
						GCOR[13]	NORAC[14]	CROR[15]	
4	§214.327	Inaccessible Track	Non-Controlled	No	Inaccessible Track	6.28*	98/141	41/ 841.(b)(i)**	Typically protected by LOTO switches (aligned away from protected route), derails, or rails physically removed from the track, in all that physically prevent train movements. Non-PTC Tracks: generally used on Non-Controlled Tracks where PTC would not be required; where adjacent approaching tracks are covered by PTC then protection would be provided by PTC. PTC Tracks: Where used on PTC controlled tracks it would, as required by the PTC regulations, to be enforced by PTC, typically, this form of protection would not be used alone, but would be supplemented with other forms of protection (switches, signals, etc.) that are integrated into the PTC system. *While Inaccessible Track is eluded to in GCOR (in Blue Flag Protection Rules and for the Protection of Occupied Outfit Cars) it is not specifically covered by a GCOR rule. It is assumed that this is left to each railroad that uses GCOR to supplement with their own rules that are incompliance with FRA Part 214. **CROR does not provide an exact equivalent to Inaccessible Track; however, it does provide for LOTO'ed switches aligned away from the work area, but not derails, portable derails, or a rail rolled out/disconnected track.
			Non-Controlled	No	Other Than Main	6.28	98	41/ 841.(b)(i)**	GCOR = Other Than Main NORAC = Movement on a Track Not Governed by ABS, DCS, or Interlocking Rules CROR = Non-Main (NMT)
			Controlled	Yes	Block Register Territory (BRT)	6.15	N/A	N/A	
5	§214.318	Locomotive Servicing and Car Shop Repair Track Areas	Non-Controlled	No	Blue Flag Protection	5.13	16	26	Use to protect personnel working on/under trains. Typically used in yard areas or other tracks where restricted speed limits used. Includes similar requirements to Inaccessible Track. Where used on main trains in PTC territory, the requirements for the enforced protection of the train/equipment/cars would provide the required protection. Where Blue Flag protection is used, on PTC tracks, then PTC enforcement would be provided.

Item	FRA Regulation [11]	FRA Protection Definition	Track Controlled or Non-Controlled	Enforced by PTC[12]	Example Rule Description	Example General Rules			Notes
						GCOR[13]	NORAC[14]	CROR[15]	
6	§214.329	Train Approach Warning Provided by Watchmen/ Lookouts	Both	No	Train Approach Warning (TAW)	N/A	N/A	N/A	Not specifically covered in GCOR/NORAC/CROR, rules typically housed in each separate railroad's Roadway Worker Protection (RWP) Manual.
7	§214.336	On-Track Safety Procedures for Certain Roadway Work Groups and Adjacent Tracks	Both	Limited	Adjacent Track Protection	N/A	N/A	N/A	Not specifically covered in GCRR/NORAC/CROR, rules typically housed in each separate railroad's RWP Manual. PTC protection would only be provided if Adjacent Track Protection is provided by certain forms of protection, integrated into PTC on Controlled Track. With other forms of protection, such as Watchman/Lookout or Inaccessible Track would not necessarily be protected by PTC.
8	§214.337	On-Track Safety Procedures for Lone Workers	Both	No	Independent Train Protection (IDT)	N/A	N/A	N/A	Not specifically covered in GCRR/NORAC/CROR, rules typically housed in each separate railroad's RWP Manual. The primary form of protection is the lone worker self-detection of trains (where the Lone Worker acts as their own Watchmen/ Lookout, aka: IDT – Individual Train Detection). Lone Workers, have the sole right to require additional protection, in lieu of IDT, which, in PTC territories would provide additional protections.
9	§214.331	Definite Train Location	Both	N/A	N/A	N/A	N/A	N/A	Definite Train Location mandated to be abolished by FRA no later than June 12, 2017.
10	§214.333	Informational Line-Ups of Trains	Non-Controlled	N/A	N/A	N/A	N/A	N/A	Informational Line-Ups of Trains mandated to be abolished by FRA no later than June 12, 2017.

Abbreviations and Acronyms

ACRONYM	DEFINITION
ABS	Automatic Block Signal System
ACSES	Advanced Civil Speed Enforcement System
APTA	American Public Transit Association
AREMA	American Railway Engineering Maintenance of Way Association
ASES	Advanced Speed Enforcement System
ASLRRA	American Short Line Railroad Association
ATC	Automatic Train Control
BOS	Back Office Server
BRT	Block Register Territory
CAD	Computer Aided Dispatching
CBTC	Communications-Based Train Control
CFR	Code of Federal Regulations
CROR	Canadian Rail Operating Rules
CTC	Centralized Traffic Control
DBOM	Design, Build, Operate, Maintain
DCS	Form D Control System
DOT	U.S. Department of Transportation
E-ATC	Enhanced Automatic Track Control
EIC	Employee-in-Charge (see RWIC)
EIC-PRT	Employee-in-Charge Portable Remote Terminal
ETMS	Electronic Train Management System
FRA	Federal Railroad Administration
GCOR	General Code of Operating Rules
GPS	Global Positioning System
IDT	Independent Train Detection
I-ETMS®	Interoperable Electronic Train Management System (trademark of Wabtec Corporation), formerly Vital Electronic Train Management System
I-ITCS	Interoperable Incremental Train Control System
ITC	Interoperable Train Control
LOTO	Lock-Out/Tag-Out
MGT	Million Gross Tons
MOW	Maintenance of Way
MP	Milepost

ACRONYM	DEFINITION
NORAC	Northeast Operating Rule Advisory Committee
OCS	Occupancy Control System
PIH	Poison Inhalation Hazard (see TIH)
PTC	Positive Train Control
RSIA'08	Rail Safety Improvement Act of 2008
RWIC	Roadway Worker-In-Charge (see EIC)
RWP	Roadway Worker Protection
SCT	Siding Control Territory
SOW	Statement of Work
TAW	Train Approach Warning
TC	Transport Canada
TIH	Toxic Inhalation Hazard (see PIH)
TOP	Track Occupancy Permit
TTCI	Transportation Technology Center, Inc. (the company)
TWC	Track Warrant Control
USDOT	U.S. Department of Transportation
VTI	Vehicle Track Interaction