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Maintenance-of-Way (MOW) Employee Safety System – Phase 1

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DOT/FRA/ORD-19/15

Final Report
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13. ABSTRACT (Maximum 200 words)
The Federal Railroad Administration (FRA) contracted Transportation Technology Center, Inc. (TTCI) to develop a concept of operations (CONOPS) for a system capable of resolving the location of Maintenance-of-Way (MOW) workers and establishing working limits, and the initial applications that could utilize this information for enhanced safety and other potential functions. The proposed MOW Employee Safety System (MOWESS) is not a single system, rather it is a set of risk reducing applications that are intended to improve MOW worker safety by reducing specific risks.

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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)

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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)

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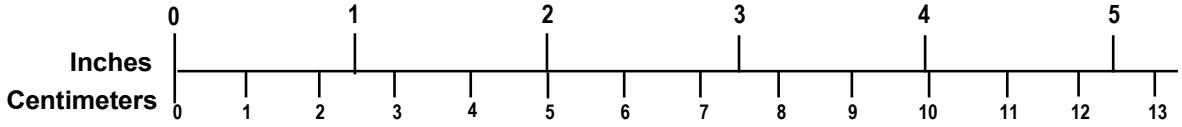
QUICK INCH - CENTIMETER LENGTH CONVERSION



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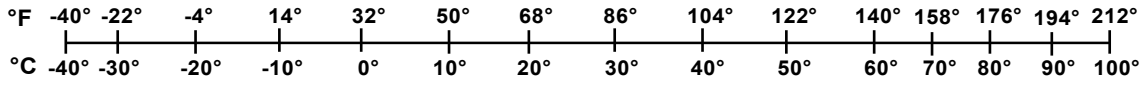

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Executive Summary

The Federal Railroad Administration (FRA) sponsored Transportation Technology Center, Inc. (TTCI) to develop a high-level concept of operations (CONOPS) document for a Maintenance-of-Way Employee Safety System (MOWESS). The work was conducted from June 2017 to August 2018 at the Transportation Technology Center (TTC) near Pueblo, CO. The proposed MOWESS is not a single system, rather a set of risk-reducing applications that are intended to improve maintenance-of-way (MOW) worker safety by reducing specific risks.

Development of the system concepts for the MOWESS applications included three distinct subtasks:

- Developing operational use cases for the MOW roadway worker
- Conducting a preliminary hazard analysis (PHA) of the use cases to identify specific risks to be addressed by the MOWESS applications

Development of the MOWESS application CONOPS, based on the information established in the first two subtasks, MOWESS applications are meant to provide information and alerts to the MOW worker while being afforded on-track safety by established protection methods. The user platform for the system is conceived as a small, portable device carried by the MOW worker and used in a variety of modes, subject to situational needs.

The MOWESS is not intended to replace current MOW protection methods. MOWESS is a proposed supplemental system designed to work in conjunction with established MOW protection methods to enhance worker situational awareness and reduce hazards while performing job functions in a MOW environment.

1. Introduction

The Federal Railroad Administration (FRA) and the railroad industry are interested in employing technology capable of resolving the location of roadway workers and establishing working limits. This information could be used to improve situational awareness of individual workers and the employee in charge (EIC) of roadway worker safety.

Transportation Technology Center, Inc. (TTCI) conducted a research project that investigated the operational use cases and hazards associated with Maintenance-of-Way (MOW) workers and concepts for a MOW Employee Safety System (MOWESS) used to help mitigate these hazards. This document describes the work conducted and summarizes key results.

1.1 Objectives

There were three main objectives of this project:

- To develop MOW operational use cases based on input received from the advisory group (AG).
- To develop a preliminary hazard analysis (PHA) to identify and categorize hazards associated with the MOW operational use cases.
- To develop a high-level Concept of Operations (CONOPS) for the initial set of roadway worker safety applications, with FRA and industry AG input.

1.2 Background

Based on data reported to FRA, railroad workers suffer hundreds of casualties (deaths and injuries) each year as a result of accidents that occur within MOW work zones. These accidents also result in significant damage to equipment and property. One contributing factor in many of these incidents is a lack of or degraded situational awareness.

To address this concern, FRA and the railroad industry are interested in employing technology capable of resolving the location of roadway workers and establishing working limits. This information could be used to improve situational awareness of individual workers and the EIC of roadway worker safety.

1.3 Overall Approach

To achieve the stated objectives, TTCI organized and worked with an industry AG to facilitate consensus on the overall system concepts and use cases. TTCI developed operational use cases relevant to the needs of the railroads, based on current practices for establishing and maintaining MOW safety protection in a variety of scenarios. Once the operational use cases were identified, a PHA was conducted to determine hazards associated with each of the operational use cases. The results of the PHA identified and categorized the hazards into groups and paired them with risk mitigation approaches. When the PHA was complete, a suite of MOWESS application concepts were developed that could be implemented to provide information to the MOW worker and EIC to reduce risk and prevent hazards associated with MOW work.

1.4 Scope

The work performed in this project was focused on development of high-level concepts for a system capable of resolving the location of MOW workers, establishing working limits, and providing information to the MOW worker to enhance their situational awareness. Information from the AG and stakeholder needs, were used to develop the concepts for MOWESS.

The project scope for this phase included the following:

- To assemble an industry AG to provide input and review.
- To work with the AG to identify the initial set of applications and functions using roadway worker location monitoring information.
- Developed a CONOPS for the initial set of roadway worker location monitoring functions and use cases.

Development of system requirements, conducting technology assessments, and developing or testing potential technology solutions were all out of scope for the initial phase of work described in this report.

1.5 Organization of the Report

This report was organized into three main sections. Section 1 describes the tasks of this project and the work performed. Section 2 reviews the results of the work performed. Section 3 describes the results, while Section 4 provides recommended future phases for the MOWESS program.

2. MOWESS Tasks

The MOWESS project was divided into two main tasks. These tasks included assembling an AG with representatives from freight and passenger railroads and developing a CONOPS for a suite of applications to enhance situational awareness of the MOW worker.

2.1 Industry Advisory Group

TTCI assembled an AG that included representatives from the railroad industry:

- Class I railroad MOW safety and train control representatives
- FRA
- Short line railroads (i.e., American Short Line Railroad Association, etc.) MOW safety representatives
- Commuter/passenger agencies (i.e., American Public Transportation Agency, etc.)

2.2 MOWESS Concept of Operations

The proposed MOWESS is not a single system, rather it is a set of risk reducing applications that are intended to improve MOW worker safety by reducing specific risks. Development of the system concepts for the MOWESS applications included three distinct subtasks: (1) developing operational use cases for the MOW roadway worker, (2) conducting a PHA to identify the specific risks to be addressed by the MOWESS applications, (3) and development of the MOWESS application concepts, based on the information developed in the first two subtasks.

2.2.1 *Operational Use Cases*

The purpose of the MOW worker operational use cases is to describe current railroad operating practices and scenarios associated with establishing and maintaining roadway worker protection. The use cases were identified to represent the base cases for development of the PHA. The use cases were established from the MOW perspective and assume that all safety rules for establishing and maintaining protection were followed. The use cases include all the methods for gaining access to track in single, double, triple, and quad track territory from the perspective of each MOW worker protection method. The operational use cases are included in Appendix A.

The use cases were developed based on current practices for roadway worker protection, derived from operating rules (including the General Code of Operating Rules [GCOR], and the Northeast Operating Rules Advisory Committee [NORAC] operating rules,) and roadway worker protection rules from Title 49 Code of Federal Regulations (CFR) Part 214 [2]. The use cases were grouped into sets, based on the methods of establishing roadway worker protection. A description of MOW worker protection methods as used in the operational use cases is provided below.

Lone Worker

A lone worker is an individual roadway worker[1] who is not being afforded on-track safety[2] by another roadway worker (see footnote number 1), who is not a member of a roadway work group,[3] and who is not engaged in a common task with another roadway worker (see footnote number 1). A lone worker is responsible for his/her own safety while on track or within the foul of track. The lone worker must be able to see approaching trains with enough advance warning to be clear of the track 15 seconds before a train's arrival [2].

Watchman/Lookout

An annually trained and qualified employee who provides a warning to roadway workers of approaching trains or on-track equipment. The watchman/lookout must be properly equipped to provide visual and auditory warning such as whistle, air horn, white disk, red flag, lantern, and fusee. A watchman/lookout's sole duty is to look out for approaching trains/on-track equipment and provide adequate time for workmen to be positioned in the clear no less than 15 seconds before the arrival of trains/on-track equipment [2].

Train Coordination

A method of establishing Working Limits on track which a train holds exclusive authority to move whereby the crew of that train yields that authority to a roadway worker.

Train coordination provides the ability for workers and their equipment to use a train's authority to establish working limits. The employee must contact the train's engineer to request use of train coordination. To establish working limits:

- The train must be in view and stopped.
- The EIC of working limits will communicate with the engineer who will notify other crew members that working limits are to be established.
- The engineer will make movements only as permitted by the EIC until the working limits have been released to the engineer.
- The train will not release its authority within the limits until those working limits have been released by the EIC [2].

Exclusive Occupancy

Exclusive track occupancy is used to establish working limits on controlled tracks. Exclusive track occupancy is requested by the EIC and issued by the train dispatcher or control operator. When MOW exclusive occupancy is established, train movement on the segment of MOW occupied track are held clear by the authority of the dispatch or control operator. The procedure depends upon communication of precise information between the train dispatcher or control

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[1] 49 CFR § 214.7, Roadway worker

[2] 49 CFR § 214.7, On-track safety

[3] 49 CFR § 214.7, Roadway work group

operator, the roadway worker in charge of the working limits, and the crews of affected trains [1] [2].

Track Bulletin

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

- Subdivision
- Specific work limits
- Start and finish time
- Track(s) affected
- MOW EIC, Foreman, and MOW work crew names [2]

Joint Occupancy

Joint Occupancy is the processes by which a separate roadway work group is afforded on-track safety by the EIC of a pre-established exclusive track occupancy, and that is located away from the EIC of the pre-established exclusive track occupancy. If Positive Train Control (PTC) is available, then PTC system components enforce train movement authority (MA) limits and provide train crew information as denoted in the scenario steps [2].

Each set of use cases was given an identifier for traceability through the PHA and other future tasks.

Within each set of use cases, individual use cases were developed based on the reference track configuration for the use case. Nine different reference track configurations were established, with the intent of covering the range of track configurations from simple single track configurations, to configurations involving multiple tracks, sidings, crossovers, and diverging tracks.

A set of rules was established for use case development, with the objective of capturing the proper level of system detail and required elements for conducting the PHA and future tasks. The details of the rules for use case development, as well as the full description of each use case can be found in the Operational Use Case document in Appendix A.

2.2.2 Preliminary Hazard Analysis

The PHA utilizes operational use cases to develop a matrix of potential hazards. These hazards then can be categorized into hazard groups. The resulting hazard groups identified through the PHA, combined with the operational use cases, provide the basis for the MOWESS concepts and the hazards the system is intended to prevent.

To perform the PHA, a spreadsheet was developed that identified, described, and categorized the potential MOW roadway worker hazards. Within the spreadsheet document, a separate tab was created for each of the methods of roadway worker protection described in Section 2.2.1. Within

each method of roadway worker protection, potential hazard conditions were identified and given a specific identifier. Each hazard describes a scenario or condition that has the potential to cause an incident or mishap.

For each of the hazard conditions identified, one or more potential hazard causes were determined and listed. Hazard causes describe the events that could lead to the identified hazard. In many cases, there are multiple distinct events that can create the same hazardous condition, and each of these were given a separate row in the PHA sheet. For each of the hazards and hazard causes, a description of the effect(s) and resulting potential mishap also were included. In many cases, multiple potential mishaps could result from the same hazard and each of these were given a separate row in the PHA sheet.

Although the causes are specific to the hazard and the events that could lead to them, it was possible to categorize these into more general types of hazard causes or groups. This is useful for generalizing the types of causes that the MOWESS system should be designed to help mitigate. In addition to the data described previously, a hazard group was assigned to each hazard cause. The hazard groups identified by the PHA includes:

Miscommunication – Miscommunication is any error in relaying a message that causes the meaning to be misunderstood. MOW worker miscommunications can result in a failure to clear a hazardous situation. An example of this is, while working under the rules of Joint Occupancy, the EIC of the primary workgroup gives the order to that workgroup to clear the track for the movement of MOW equipment by the secondary workgroup. The EIC of the primary workgroup receives what he/she believes to be "Clear Track" radio messages from all members of the workgroup. However, one of the radio transmissions was not clear and what the EIC heard as "Clear of track" was actually "Not clear of track for another 5 minutes." As a result, the EIC of the primary workgroup gives the EIC of the secondary workgroup permission to move on-track equipment through the area of track where members of the primary workgroup are still working. This miscommunication, potentially caused by a faulty radio transmission, introduces the potential risk of accidents, or even fatality, to the members of the primary workgroup still working on track.

Inattention – Inattention is the failure of a MOW worker to give full attention to a situation resulting in a loss of situational awareness. MOW worker inattention can lead to not being able to clear a hazardous situation in time. An example of this is inattention while working under the rules of Watchman/Lookout. While working as a watchman/lookout, the watchman is responsible for alerting the on-track worker of approaching trains and other potential hazards such as on-track equipment. This alert should allow for the on-track worker to safely be in the clear of the track no less than 15 seconds prior to train arrival at the worker's location. While working, the watchman was distracted by another railroad employee who stopped to talk. The conversation introduced a brief moment of inattention by the watchman. Due to this inattention, they did not notice a train approaching until too late. This situation introduces a potentially severe hazard to the on-track worker and their equipment.

Incorrect Individual Train Detection (ITD) Assessment – An incorrect ITD assessment is the failure of the MOW roadway worker to correctly determine timetable train speed, available sight distance, or the amount of time required to clear the track. An ITD will require reassessment while performing work if any of these three factors change. If a lone worker would like to access track, it is their responsibility to perform an ITD prior to entering the foul of the track. Similarly,

it is the responsibility of the watchman/lookout to properly assess ITD prior to allowing workers to enter the foul of track. An example of an incorrect ITD assessment may be due to a change in weather conditions. For example, a lone worker arrives at the place on the track where he/she needs to take a photo of a switch. While performing the ITD worksheet prior to accessing the foul of the track, it begins to lightly rain. The MOW worker does not take the rain into account because it is light. By the time the ITD is finished it has begun to rain heavily. The lone worker fouls the track to take a photo but does not notice the train approaching due to the noise and poor visibility from the rain. This situation increased the hazard of severe injury or death due to the ITD being done incorrectly.

Workmen Incapacitated – An incapacitated workman is any workman that is not able to clear the foul of the track due to a physical impairment. For example, if a MOW work crew are working under 49 CFR § 214.321, Exclusive Track Occupancy, and the authority is nearing its end time granted by the dispatcher, the EIC will radio each of the members of the work crew to notify them to clear track. Each of the workmen will then radio the EIC to confirm they have cleared the foul of the track. If one of the workmen working in a remote location is incapacitated, he may not able to clear the track or to answer the EIC's call to the clear the track.

The PHA is included in Appendix B.

2.2.3 MOWESS Applications

This section is intended to describe the tasks associated with development of the MOWESS concepts and documentation within the CONOPS. Additionally, an example of a potential MOWESS application is provided. The full suite of MOWESS applications are detailed in the CONOPS document included in Appendix C.

The MOWESS concepts were derived from the hazards identified in the PHA and the operational use cases previously identified and described. It was established that, unlike PTC or similar enforcement systems, the MOWESS would not be a system designed to force the roadway worker into a safe condition, but rather to provide information to enhance situational awareness. It was similarly established that the system would be considered a non-vital system to provide supplementary information to the roadway worker, as opposed to replacing any existing operating rules. Several constraints were also identified, relating to the use of non-ubiquitous wireless communications and elements related to the non-fail-safe architecture conceived.

As mentioned previously, the MOWESS is not envisioned as a single system, but rather a set of applications specific to the roadway worker situation and with the intent of reducing risk associated with the given situation. The user platform for the system is conceived as a small portable device that the roadway worker could wear that could be used in a variety of modes, subject to the situational needs. The intent of the CONOPS is to describe all of the potential MOWESS applications.

Each MOWESS application was developed based on identified methods or functions to reduce risk associated with the hazard groups identified from the PHA. For each of the applications identified, a description was developed and included in the CONOPS, including items such as objectives of the application, high-level architecture diagrams, and descriptions of how the application would be used, as referenced to an example use case from the previously defined operational use cases.

As an example of the type of information included in the CONOPS, how one of the MOWESS applications (the train location application) might be utilized in one example use case is provided in Table 1. The information in this table is an example of how MOWESS could be used in the situation of Use Case UC-RWP-105 from Appendix A.

Table 1: MOWESS Train Location—Lone Worker Double Track

MOWESS Train Location	Lone Worker Double Track
ID	MOWESS UC-RWP-105
Title	Lone Worker with Train Location Application – Double Track
Description	Lone worker (LW) must foul track Main 1 to perform inspection or minor adjustment/repair. Lone worker is equipped with MOWESS Train Location Application. Road train on track Main 2 approaches work area.
Method of Operation	Any
RR Personnel	LW, train crew (TC)
RR Systems	Road Train
Reference Track Configuration	Double track per Section 4.1.5
Initial Condition	1) LW determines maximum train speed. 2) LW determines clear time. 3) LW determines site distance available. 4) LW determines site distance required. 5) Track Main 1 to be accessed by LW is unoccupied. 6) Lone worker verifies MOWESS Application is active and determines train location *7)* LW accesses track Main 1 and begins work if ITD is acceptable.
Trigger Event	Road train on track Main 2 approaches track segment occupied by LW.
Scenario Steps	1) LW observes MOWESS Train Location Application display that shows train occupancy in nearby signal block. Focusing LW attention of train approach. 2) LW observes road train approaching. 3) TC blows whistle. 4) LW clears track Main 1. 5) TC proceeds through track Main 2 segment.
End State (Happy Path)	1) LW cleared track. 2) Road train proceeded.
References	49 CFR § 214.337, 49 CFR § 214.339, and GCOR 5.8

Similar tables were created for each MOWESS application described in the CONOPS. The intent is to provide the reader with enough detail about the application to understand the basic concept of the application, including under what types of conditions it would be used, what personnel would be involved, and how the system would be used in the scenario. A more thorough

development of every use case associated with each application was not included, but could be developed if needed to further develop the concept.

The following applications were identified and are described in greater detail in the CONOPS:

- MOWESS Train Location Application
- High Accuracy Train Location Application
- Train Approach Detection Application
- Watchman Warning System
- MOW Worker Position Monitoring

3. MOWESS Concept and Potential Application

The MOWESS was conceived as a technology capable of resolving the location of roadway workers and establishing working limits. The information provided by the MOWESS could be used to improve situational awareness and improve safety of individual workers and the EIC. Based on the findings of the operational use cases and corresponding PHA, several MOWESS applications were identified in the CONOPS included in Appendix A. These applications, if used properly in conjunction with current practices, have the potential to greatly increase the information provided to the MOW workers and the EIC, providing them with the means to reduce or avoid potential MOW hazards. The applications could be used to track MOW worker location as well as provide virtual boundaries to the MOW work zone. Some applications can provide the exact train location as well as speed and direction of travel. The train information provides the MOW worker and EIC a means of enhanced situational awareness before and while accessing the track. The MOWESS is intended to function as a supplemental system to current practices to improve overall safety of the MOW worker.

4. Future MOWESS Projects

Future project development phases may include an informal survey of the industry to identify technologies already in use that may provide some of the intended functionality or similar functionality in the area of MOW work zone limits monitoring and alerting. Development of system requirements and interface control documents defining data and messages to be generated by roadway worker MOWESS equipment could be developed to further define the details of the system and be used in procurement requests to develop a functional prototype. Future phases may also include contracting with selected vendor(s) to develop a proof-of-concept MOW work zone limits monitoring and alerting systems, as well as testing the functionality of the proof-of-concept MOW work zone limits monitoring and alert systems against system requirements at the Transportation Technology Center (TTC) and in revenue service.

5. References

1. General Code of Operating Rules Committee. (2015, April 1). General Code of Operating Rules. Seventh Edition.
2. Government Printing Office. (n.d.). 49 CFR Part 214, § 321–349, Ch. II (10–1–11 Edition).

Appendices

Transportation Technology Center. (2019). Maintenance of Way (MOW) Employee Safety System – Phase 1: Appendices A Through C. Washington, DC: U.S. Department of Transportation, Federal Railroad Administration.

Abbreviations and Acronyms

Abbreviations and Acronyms	Definition
AG	Advisory Group
CFR	Code of Federal Regulations
CONOPS	Concept of Operations
EIC	Employee in Charge
FRA	Federal Railroad Administration
GCOR	General Code of Operating Rules
GPS	Global Positioning System
ITD	Individual Train Detection
LW	Lone Worker
MOW	Maintenance-of-Way
MOWESS	Maintenance-of-Way Employee Safety System
MA	Movement Authority
NORAC	Northeast Operating Rules Advisory Committee
PTC	Positive Train Control
PHA	Preliminary Hazard Analysis
TC	Train Crew
TTC	Transportation Technology Center
TTCI	Transportation Technology Center, Inc.
WM	Watchman