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Canadian Rail Research Laboratory

Report on

Enhanced Train Control

Prepared for

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Executive Summary

This report summarizes the Canadian Rail Research Laboratory's (CaRRL) findings after performing an in-depth investigation into the potential safety benefits gained from the introduction of enhanced train control (ETC) technology to the Canadian railway environment. CaRRL was contracted by Transport Canada (TC) to perform this study as a follow-up to a previous ETC study performed by the Train Control Working Group (WG), the final report from which was submitted to the Advisory Council on Railway Safety (ACRS) in September 2016.

The mandate provided to CaRRL included four key components:

1. Clearly define the functionality of a potential ETC system;
2. Perform a detailed assessment of Railway Occurrences Database System (RODS) records to accurately characterize the proportion of ETC-preventable occurrences;
3. Develop risk prioritization criteria for ETC implementation in Canada; and
4. Apply the risk prioritization criteria and perform a risk analysis for select rail corridors.

This report is subdivided into two complementary parts. Part A addresses the first two mandate items, while Part B addresses the final two. While this report is structured in two halves, the results presented and discussed in Part B are intimately reliant on the assumptions and analyses made in Part A.

ETC System Functionality

The ETC system envisioned by CaRRL consists of a four-tiered hierarchical framework, with subsequent levels building on the previous in terms of complexity and functionality. A hierarchical system framework was adopted because the WG report indicated a "one size fits all" ETC approach would not be appropriate in the Canadian railway environment. ETC Level 1 through 3 systems are designed as overlays on the existing train control system, while the ETC Level 4 system includes a complete replacement of the existing train control infrastructure. All four of the ETC systems proposed in this report are theoretical in nature but the ETC Level 1 through 3 systems should be implementable with existing technologies. The implementation of the Level 4 ETC system would require significant additional technological development.

The ability of an ETC system to prevent an incident is directly dependent on the functionality designed into the system. In recognition of this dependency the first step undertaken by CaRRL was to fully define the functionality of the proposed ETC system(s) under review. For the purpose of this analysis, CaRRL chose to closely parallel the US Positive Train Control (PTC) system's core functional objectives.

- Prevention of over speed derailments;
- Prevention of train to train collisions;
- Prevention of train occupying improperly aligned switches; and
- Prevention of train entering a foreman's work authority.

The most basic ETC system envisioned by CaRRL (Level 1) is a crew assist and monitoring system that is minimally invasive and locomotive centric (i.e., no buildout into the wayside). ETC Level 2 is a crew assist and enforcement system that incorporates an interface with the train braking system (allowing the system to stop a train instead of only issuing warnings) and selective buildouts into the wayside through the monitoring of key switches. The ETC Level 3 system further increases in complexity by including, amongst other features, full buildouts into the wayside and positive enforcement of operating authorities. The Level 3 ETC system is intended to closely parallel the US PTC system. Finally, the Level 4 system involves a complete re-design of existing train control infrastructure into a communication-based moving block system. At Level 4, all requirements for wayside signalling would be eliminated and all operating authorities would be contained within the ETC system.

Detailed RODS Assessment

RODS is maintained by the Transportation Safety Board of Canada (TSB) and contains information on federally reportable railway incidents. CaRRL performed their ETC assessment on an extracted version of the RODS database provided by the TSB in spring 2017. It is important to note that the RODS database is continuously updated while the download provided to CaRRL is a static snapshot that will not include revisions or alterations incorporated after spring 2017. CaRRL focused their assessment on the 14,036 occurrences reported in the ten-year period between January 1, 2007 and December 31, 2016 within the provided RODS dataset.

To assess whether individual occurrences would have been ETC preventable, a number of assumptions are required to 1) describe how and where the ETC system would be installed and operated and 2) address specific operational circumstances encountered during the assessment. Both sets of assumptions are critical to the final results as different assumptions would alter whether specific occurrences would be ETC preventable or not. For occurrences determined to be ETC preventable, the minimum ETC Level required for occurrence prevention and key system functionality are identified. If an occurrence is determined to be non-ETC preventable, the primary impediment to ETC preventability is identified; however, multiple factors may render an occurrence not preventable with ETC.

The RODS database includes many categories of occurrences that are not preventable by typical ETC systems and technologies. For this reason, it was expected that the proportion of all RODS occurrences that would have been ETC preventable would be small. ETC functionality was expected to achieve much more substantial occurrence preventability in the targeted areas where the system was intended to be of benefit. To provide as full of an analysis as possible, CaRRL has performed three separate preventability assessments:

1. ETC preventability for all occurrences in the snapshot of the RODS dataset,
2. ETC preventability for Movement Exceeds Limits of Authority-type occurrences, and
3. ETC preventability for Main-Track Train Collisions and Derailments.

The breakdown in ETC preventability considering all 2007-2016 RODS occurrences is as follows:

- Level 1 ETC system → 3.55% of all 2007-2016 RODS occurrences (498 of 14,036)
- Level 3 ETC system → 4.57% of all 2007-2016 RODS occurrences (642 of 14,036)
- Level 4 ETC system → 5.96% of all 2007-2016 RODS occurrences (837 of 14,036)
- Not ETC preventable → 94.04% of all 2007-2016 RODS occurrences (13,199 of 14,036)

No preventability is presented for the Level 2 ETC system as it is an intermediary between Levels 1 and 3 and preventability will depend on the individual switches monitored. The total numbers of ETC-preventable occurrences at each Level are dominated by Movement Exceeds Limits of Authority (MELA) type occurrences. The specific breakdown in preventability by ETC Level considering only MELA-type occurrences is;

- Level 1 ETC system → 36.64% of all 2007-2016 MELA occurrences (463 of 1,168)
- Level 3 ETC system → 45.12% of all 2007-2016 MELA occurrences (527 of 1,168)
- Level 4 ETC system → 58.39% of all 2007-2016 MELA occurrences (682 of 1,168)
- Not ETC preventable → 41.61% of all 2007-2016 MELA occurrences (486 of 1,138)

ETC preventable MELA-type occurrences include those where the proposed ETC functionality was intended to provide the most benefit including prevention of trains passing signals at stop, exceeding the limits of their authority as well as unauthorized entry into foreman's authorities.

A review of only the combination of RODS-reported main-track train collisions and main-track train derailments (rail accidents) between 2007 and 2016 identified the following ETC preventability:

- Level 1 ETC system → 2.16% of all 2007-2016 RODS occurrences (22 of 1,018)
- Level 3 ETC system → 3.24% of all 2007-2016 RODS occurrences (33 of 1,018)
- Level 4 ETC system → 3.93% of all 2007-2016 RODS occurrences (40 of 1,018)
- Not ETC preventable → 96.07% of all 2007-2016 RODS occurrences (978 of 1,018)

The full RODS ETC assessment results highlight that only a very small proportion of all 2007-2016 occurrences would be preventable with implementation of any of the four Levels of the ETC system; although the ETC system was not expected to prevent all RODS occurrences. Within key occurrence type categories (ex. MELA or Main-Track Train Collisions and Derailments) where ETC is expected to provide key incident preventability, there are significant numbers of ETC preventable occurrences. In addition, the least complex ETC system (incorporating the Level 1 functionality) provides a large component of overall preventability.

One occurrence category where the majority of overall preventability is not predominantly associated with the ETC Level 1 functionality is main-track switch in abnormal position. For these types of occurrences, only 4 of the 82 total occurrences (4.88%) were preventable at ETC Level 1, while 66 occurrences (80.49%) would have been preventable at ETC Level 3. For the main-track switch in abnormal position category, ETC Level 4 provided no additional occurrence preventability. ETC preventability being heavily weighted towards Level 3 for main-track switch in abnormal position type occurrences is a consequence of the proposed functionality not including universal switch monitoring until Level 3.

Corridor Risk Assessment, Risk Prioritization Criteria, and Cost-Benefit Analysis

To facilitate the corridor-based assessment, the full RODS database was broken down into 19 mainline (> 10 MGT) corridors (comprised of 78 associated subdivisions) defined by Canadian National (CN) and Canadian Pacific (CP). These 19 corridors contain 62% of all 2007-2016 RODS occurrences.

As raw occurrence counts within each corridor will be subject to changes in the operational environment (track usage), an attempt was made to normalize the ETC preventability results by considering the track class, existing control method, 2016 train miles, and 2016 train counts. These data were also provided to CaRRL for each subdivision. While the normalization results suggest that implementing the ETC system will result in a greater rate of RODS occurrence prevention in corridors with existing occupancy control system (OCS) or OCS/ABS (automatic block system) + centralized traffic control (CTC) (mixed) train control systems, the results can be misleading as these corridors also exhibit the least amount of usage (train volumes). The potentially misleading normalization results clearly demonstrate the need for a risk-based assessment of ETC implementation.

The impact of ETC implementation on rail transport risk for specific corridors is evaluated following two methodologies:

1. Normalized ratios developed from the full RODS database based on train miles, existing control method, and track class; and
2. 2007-2016 corridor-specific observations.

In addition to evaluating the number of occurrences that would have been prevented through ETC implementation, severity indicators are used evaluate the reduction in the consequences of these incidents. The severity indicators CaRRL adopted are derived from information in RODS and include:

- Number of rolling stock involved in the occurrences;
- Number of rolling stock derailed in the occurrences;
- Number of cars involved transporting dangerous goods (DG);
- Number of occurrences with serious injuries; and
- Number of fatalities.

The following table summarizes the proportion of each severity indicator that would be preventable depending on the specific ETC Level implemented. These data are derived considering every occurrence category within the RODS dataset, whether they contain ETC-preventable occurrences or not (see Tables 1-9 and 1-10 in Part A).

Severity Indicator	Proportion That Would Have Been Prevented			
	Non-ETC Equipped	ETC Level 1	ETC Level 3	ETC Level 4
Number of Occurrences	0.00%	3.55%	4.57%	5.96%
Rolling Stock Involved	0.00%	2.39%	3.02%	3.86%
Rolling Stock Derailed	0.00%	0.85%	1.07%	1.21%
DG Cars Involved	0.00%	0.03%	0.15%	0.23%
Occurrences with Serious Injuries	0.00%	0.47%	0.47%	0.53%
Fatalities	0.00%	0.40%	0.40%	0.40%

The above table highlights that while an ETC system may prevent between 3.5% (Level 1) and 6% (Level 4) of all RODS occurrences, the proportion of each severity indicator is not reduced to the same degree. This suggests the occurrences being prevented are of an *overall* lower consequence and severity compared to those that are not. This point is further demonstrated by collecting occurrences of major consequence and observing that the primary occurrences contributing to each severity indicator are not ETC preventable. For example, 90% of railway-related fatalities are associated with either trespasser (452 of 751) or crossing (223 of 751) incidents; types of incidents that the proposed ETC system is not designed to address.

The finding that severity indicators related to the transport of dangerous goods and risk to life are not significantly affected by ETC further contributes to the discussion of the risk factors used during corridor prioritization of ETC implementation. It is the opinion of the authors that while comprehensive risk ranking should consider at minimum the risk factors recommended by the United States Federal Railroad Administration (FRA), the ranking procedure for prioritizing ETC implementation may be simplified to consider only a subset of risk factors:

- Train volume (i.e., train miles) [W1/2];
- Method of control [W4];
- Number of tracks [W5];
- Class of track [W6]; and
- Track grade and curvature [W7].

However, this ETC prioritization should be complemented by a qualitative evaluation of the amounts of dangerous goods transported with respect to exposed population and sensitive environmental areas. Weights assigned to each risk factor (W1, W4, etc.) provide a systematic methodology to elicit the experience of rail operators during the ETC prioritization process.

Finally, with the marginal overall safety benefits observed from ETC implementation (relative to all RODS-reportable occurrences), widespread implementation of ETC may clearly not be the best investment to improve overall rail safety in Canada. The proposed ETC functionality (developed to be similar to the US PTC system) attempts to address targeted safety concerns related to a small fraction of all railway incidents. The authors suggest that an optimal safety investment strategy include investigations into the key factors for the most significant severity occurrences. Results from these investigations may then lead to the incorporation of other risk mitigation technologies (ex. Intelligent Traffic Management Systems) into a different prospective ETC framework that may be more effective at reducing overall rail transport risk.

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Part A

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and

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1 Introduction

1.1 Motivation for CaRRL Study on Enhanced Train Control

In early 2017, the Canadian Railway Research Laboratory (CaRRL) was contracted by Transport Canada (TC) to perform an in-depth study of the potential safety benefits to be gained through the implementation of enhanced train control (ETC) technologies in the Canadian railway environment. This study is a follow-up to previous work completed by the Train Control Working Group (WG) and summarized in a final report submitted to the Advisory Council on Railway Safety (ACRS) in September 2016.

The WG report indicates their investigation into the application of ETC technologies in Canada began in response to a Transportation Safety Board of Canada (TSB) recommendation after the derailment of VIA passenger train no. 92 (VIA 92) in Burlington, Ontario on February 26, 2012. The derailment occurred when the train, travelling from Niagara Falls to Toronto, entered at 67 mph a crossover with an authorized speed of 15 mph. As a result of the derailment, all three members of the operating crew were fatally injured and 44 of the 70 passengers were injured to various degrees. Based on the results of their investigation (TSB incident report number R12T0038), the TSB made recommendation R13-01:

> *The Department of Transport require major Canadian passenger and freight railways implement physical fail-safe train controls, beginning with Canada's high-speed rail corridors.*

TSB recommendation R13-01 is based on the understanding that currently available technologies could have alerted the operating crew to the upcoming speed restriction and allowed the train's speed to be reduced prior to reaching the crossover, thereby preventing the derailment.

While the WG report states the VIA 92 derailment was the major precipitating incident leading to the analysis of advanced train control systems in Canada, it is not the only TSB-investigated railway incident to mention the safety benefits to be gained from an ETC-type system [or the Positive Train Control (PTC) system currently being rolled out in the United States]. Two incident reports resulting from TSB investigations in 2000 (R00M0007 and R00T0179) introduce the concept of switch aspect monitoring to increase railway safety, which is a primary

component of the US PTC system (described below). In addition, 17 TSB investigation reports between 2002 and 2016, including the VIA 92 derailment, make direct reference to the US PTC system. Table 1-1 summarizes TSB incident reports (for the period 2000 and 2016) that either make direct mention of the US PTC system or discuss some associated functionality as a manner by which safety along the railway could have been increased.

Table 1-1. Summary of TSB incident reports with direct mention of PTC or the associated functionality.

Incident Report	Year	Type of Occurrence	Relation to ETC or PTC
R00M0007	2000	Non-Main-Track Train Collision	Concept of switch monitoring
R00T0179	2000	Collision Involving Track Unit	Concept of switch monitoring
R02C0022	2002	Main-Track Train Collision	Explicit mention of PTC
R07C0040	2007	Main-Track Train Collision	Explicit mention of PTC
R07E0129	2007	Main-Track Train Collision	Explicit mention of PTC
R08W0058	2008	Main-Track Train Collision	Explicit mention of PTC
R09V0230	2009	Main-Track Train Collision	Explicit mention of PTC
R09W0118	2009	Main-Track Train Collision	Explicit mention of PTC
R10Q0011	2010	Main-Track Train Derailment	Explicit mention of PTC
R10V0038	2010	Main-Track Train Collision	Explicit mention of PTC
R11E0063	2011	Main-Track Train Collision	Explicit mention of PTC
R12T0038	2012	Main-Track Train Derailment	Explicit mention of PTC
R13C0049	2013	Main-Track Train Collision	Explicit mention of PTC
R13Q0001	2013	Main-Track Train Collision	Explicit mention of PTC
R14T0294	2014	MELA*	Explicit mention of PTC
R15D0118	2015	Main-Track Train Derailment	Explicit mention of PTC
R15T0245	2015	MELA*	Explicit mention of PTC
R15V0183	2015	Main-Track Train Collision	Explicit mention of PTC
R16D0073	2016	Misaligned Switch and Derailment	Explicit mention of PTC

*MELA: Movement Exceeds Limits of Authority

Table 1-1 shows the majority of the TSB-investigated incidents that make direct reference to the US PTC system are main-track train collisions; however, the US PTC system is also mentioned in a selection of main-track train derailment and MELA incident reports.

1.2 Synopsis of the WG ETC Report

Following TSB recommendation R13-01 being published, Transport Canada (TC) accepted the recommendation and proposed that the Advisory Council on Rail Safety (ACRS) establish the ETC WG to produce a report on fail-safe train control technology from a Canadian perspective. The WG delivered its findings and a final report to ACRS on September 20, 2016. This section outlines the major findings and recommendations included in the WG report.

The WG report is subdivided into three main parts:

1) an outline of various train control systems and technologies currently in development or in use in North America and Europe;
2) the status of these systems; and
3) an estimate of the safety benefit a US PTC-type system would have if installed on Canadian railways based on a high-level analysis of Canadian railway occurrence records.

For the purposes of this report, the main section of interest in the WG report is the final part detailing the WG analysis of the safety benefit to be gained from introducing a PTC-type train control system into the Canadian railway industry and the associated recommendations the WG made to ACRS. For the remainder of this report, the acronym 'PTC' is used to specifically reference the Positive Train Control technology currently being rolled out across the United States. The 'ETC' acronym is used to represent a broader assortment of potential train control options without referencing a specific technology.

The ETC occurrence preventability assessment performed by the WG began by compiling a list of all Canadian railway occurrences from the TSB Rail Occurrence Database System (RODS) for the period 2011-2015. The RODS database contains a complete summary of all reportable incidents and accidents that occur along Canadian railways and will be discussed in further detail in this report. The WG then performed a high-level parsing of the RODS database to identify groups of occurrences that would not have been ETC preventable. For the remaining occurrences, the WG performed a more detailed investigation to identify the proportion that would have been ETC preventable. In their assessment of the safety benefits to be gained by

introducing an ETC system to Canadian railways, the authors of the WG report envisioned a system with similar operating principles as the US PTC system.

From their high-level parsing of the RODS database, the WG identified five categories of railway occurrences they believed would contain preventable occurrences had a PTC-type system been installed. These five categories are:

1) main-track switch in abnormal position;
2) main-track train collisions;
3) main-track train derailments;
4) movement exceeds limits of authority (MELA); and
5) unprotected overlap of authorities.

For the 2011-2015 period, these categories contained 41, 26, 440, 607, and 27 individual occurrences, respectively. The WG concluded that all main-track switch in abnormal position (41), main-track train collision (26), and unprotected overlap of authority (27) occurrences would have been ETC preventable. However, the WG recognized that not all occurrences for the two remaining categories (main-track train derailments and MELA) would have been preventable even if an ETC system had been installed at the time.

To quantify the proportion of main-track train derailment occurrences that would have been preventable, the WG relied on additional data published in the annual TSB Statistical Summary of Railway Occurrences report. Based on the data presented in this TSB report, the WG concluded that 13 of the 440 main-track train derailments (2011-2015) would have been preventable. For the MELA occurrences, the WG based their assessment on a statistical analysis performed by the Railway Association of Canada (RAC) and concluded that approximately 45% of MELA occurrences would have been preventable had an ETC system been in use.

Table 1-2 summarizes the findings of the WG in terms of the number of preventable occurrences for each category where ETC was anticipated to have an effect as well as the total number of occurrences within RODS for a particular year (2011 to 2015). In total, the WG estimated that 5.6% of the 2011-2015 RODS occurrences would have been preventable with an ETC system with similar functionality to the US PTC system.

Table 1-2. Summary of the WG investigation into the number of ETC-preventable occurrences for the period 2011-2015.

Occurrence Type	Year					Total
	2011	2012	2013	2014	2015	
All RODS Occurrences	*1305*	*1287*	*1323*	*1455*	*1416*	*6786*
ETC-Preventable Occurrences						
Main-Track Switch in Abnormal Position	10	5	7	6	13	41
Main-Track Train Collision	3	6	4	9	4	26
Main-Track Train Derailment	4	3	2	2	2	13
MELA	60	47	49	55	62	273
Unprotected Overlap of Authority	7	5	4	5	6	27
Total ETC-Preventable Occurrences	*84*	*66*	*66*	*77*	*87*	*380*
Percent of ETC-Preventable RODS Occurrences	*6.4%*	*5.1%*	*5.0%*	*5.3%*	*6.1%*	*5.6%*

The WG concluded that their analysis provided a reasonable estimate for the proportion of ETC-preventable occurrences (5.6%), but the assessment of the RODS database was performed at a very high level and therefore could not be 100% accurate. Furthermore, their analysis of RODS was based only on the functionality of the US PTC system and any other functionality a Canadian ETC system might contain was not considered. Therefore, as part of their recommendations to ACRS, the WG proposed that a second detailed analysis of RODS be performed. This study would include defining the specific functionality of a potential Canadian ETC system followed by an in-depth occurrence-by-occurrence analysis of the RODS database, allowing for the specific functionality of the ETC system to be matched with individual preventable occurrences. The results of such a study would then be 1) a highly accurate estimate for the proportion of RODS occurrences that would be ETC preventable and 2) a sense of the ETC functionality that would provide the most benefit in terms of occurrence prevention without being tied to a specific system.

1.3 Brief Summary of the US Positive Train Control System: History and Functionality

As mentioned, PTC is intended to operate as a vital[1] overlay train control system and is currently being installed by railway operators in the United States to enhance operational safety. This

[1] Vital: A description applied to equipment whose correct operation is essential to the integrity of the signalling system. Most vital equipment is designed to FAIL-SAFE principles; a WRONG SIDE FAILURE of vital equipment could directly endanger rail traffic. (Institute of Railway Signal Engineers (IRSE) Glossary of Signalling and Telecommunications Terminology)

section is intended to provide a brief summary of the US PTC system, including its implementation timeline, functionality, and cost.

With the passing of the *Rail Safety Improvement Act* in 2008, railway operators in the US were given until December 31, 2015 to develop, install, test, and operate a new positive enforcement train protection system, which has come to be known as PTC. Due to the inherent complexity of developing, installing, and testing a new train control system, the 2015 deadline was pushed back by three years to December 31, 2018 (by the 2015 *Surface Transportation Extension Act*). If individual US operators can demonstrate significant progress in PTC implementation and testing, they may also apply to extend their respective deadlines for full PTC operation until 2020.

PTC is intended to enhance safety during train movements by operating as a fail-safe technology overlain onto the existing train control system. The system is integrated into existing train controls such that it is capable of actively stopping a train should the situation arise. The main operating goals of the US PTC system are to:

- prevent train-to-train collisions;
- prevent over speed derailments;
- prevent incursions into established work zone limits; and
- prevent movement through a switch left in the wrong position.

PTC is designed with four major components: locomotive, wayside, office, and communications (Figure 1-1).

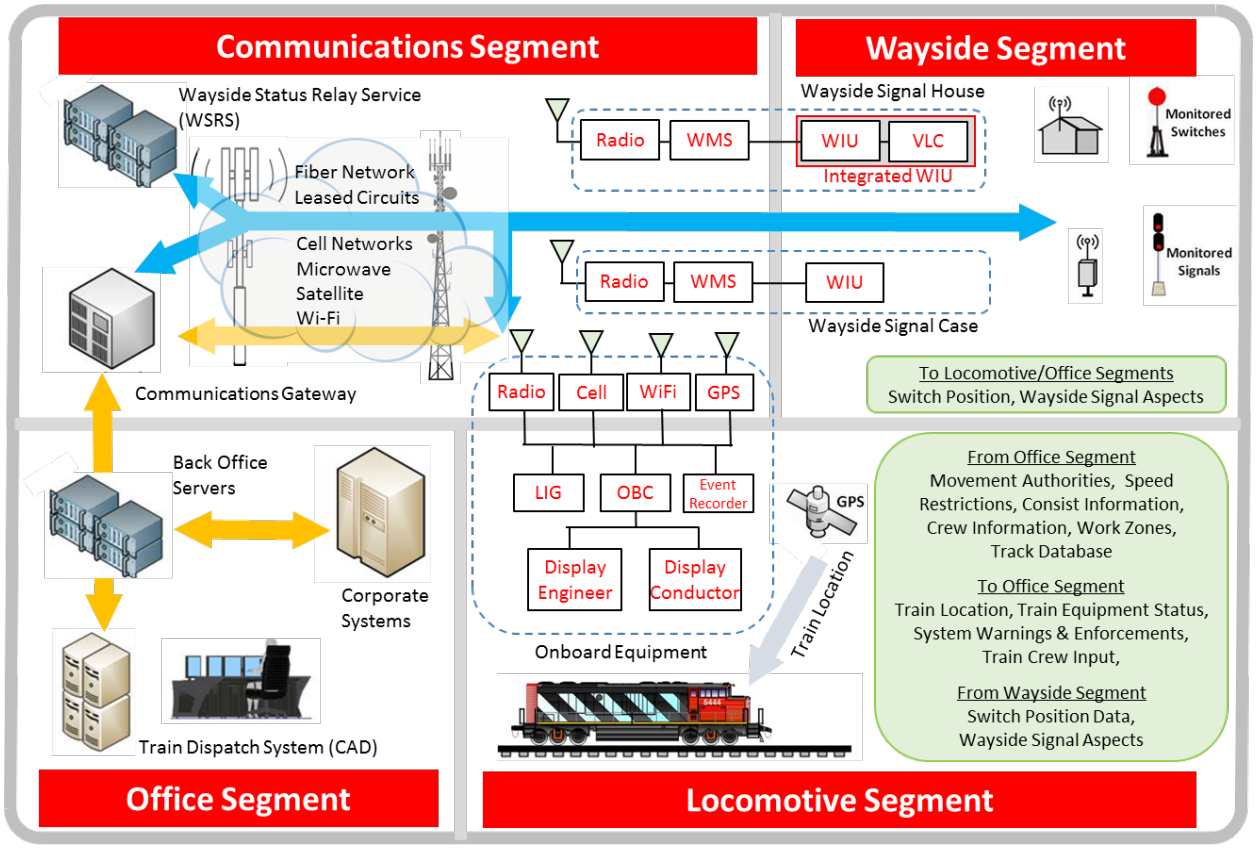

Figure 1-1. Four major components of the US PTC system (LIG: locomotive interface gateway, OBC: on board computer, WMS: wayside messaging server, WIU: wayside interface unit, VLC: vital logic controller).

The locomotive component is the portion of the system installed on the locomotive and interfaced with the existing train control systems. It is this component that is capable of actively slowing or stopping the train if required. The wayside component consists of instrumented signals and switches that collect critical aspect information (signal indications and switch positions) to be relayed to the office and locomotive components. The office component contains all data receiving and storing systems as well as the interface between the PTC system and existing train dispatching systems (servers and computers). The office component is also capable of communicating with the wayside and locomotive components. Finally, the communication component is the network (wired and/or wireless) that facilitates communication between the other three components. Examples of wireless communication networks include cellular, microwave, satellite, and Wi-Fi.

As summarized by the Association of American Railroads (AAR), the state of PTC implementation in the US at the end of 2016 was as follows:

- PTC had been installed on 38% of the required route miles (60,153 in total);
- PTC had been installed on 63% of freight rail locomotives (18,500 in total);
- PTC training had been provided to 51% of all employees who require it (125,000 in total);
- PTC had been installed on 87% of the track-side signal systems (32,654 in total); and
- 77% of communication towers had been installed (3,968 in total).

In terms of the cost to freight operators in the US, the AAR reports that, as of February 2017, the cost of PTC development and deployment had totalled more than $7.9 billion USD ($9.9 billion CAD). Additionally, the AAR identified that freight railways continue to invest in PTC at a rate of $100 million USD ($125 million CAD) per month. The estimated total cost to freight railroads for PTC deployment is expected to be $10.6 billion USD ($13.3 billion CAD) with the AAR estimating that hundreds of millions of dollars will be required on an annual basis to cover system maintenance. PTC implementation on passenger train services in the US is expected to account for an additional $3.5 billion USD ($4.38 billion CAD).
[Data sources: 1) AAR website: www.aar.org – accessed: July 24 2017 and 2) AAR Background Paper – Positive Train Control, March 2017].

The primary objective for the mandated US PTC implementation is to improve rail safety. While the railway industry supports this objective, Canadian railway operators have raised several specific concerns in regards to their experience with PTC deployment in the US. The major concerns with PTC shared by the industry are summarized as follows:

1. Large cost with little inherent benefit to operational capacity or fluidity;
2. Large system complexity required to encompass operator interchange; and
3. Reduction in operational capacity due to system outages, communication issues, and conservative breaking algorithms.

While operator experiences related to the deployment of PTC may not translate directly to the Canadian railway environment, they should be considered to provide a holistic context for any potential ETC system.

1.4 CaRRL Mandate

On the basis of the final ETC WG report, TC provided CaRRL with a mandate to further the study of ETC in Canada by:

1) clearly defining the functionality of a potential ETC system;
2) performing a detailed assessment of the RODS database to accurately identify the ETC-preventable occurrences (based on the proposed functionality);
3) developing risk prioritization criteria for ETC implementation in Canada; and, finally,
4) applying their risk prioritization criteria and perform a risk analysis for a select rail corridors.

This report contains the results for the first two components of CaRRL's mandate. This report begins by describing the proposed ETC functionality, followed by an overview of the railway occurrence data used in the assessment as well as an outline of how the assessment was performed. Finally, the assessment results are presented and discussed.

2 Proposed ETC Functionality

2.1 Functionality Overview

The ability of an ETC system to prevent railway accidents and incidents is directly dependent on the functionality incorporated into the system design. Therefore, the first step in performing an ETC incident preventability analysis is to clearly define the functionality of the ETC system being assessed.

As noted by the original Working Group investigation, a number of different types of ETC systems are currently being developed, each with unique functionality and therefore differing capabilities with respect to preventing railway incidents. The Working Group also concluded that a "one size fits all" approach to ETC implementation was not appropriate for the Canadian Railway industry.

2.2 ETC Hierarchy

Based on the plurality of ETC systems under development and the conclusion that "one size fits all" is not suitable for ETC implementation in Canada, the incident preventability analysis was performed for a hierarchy of different ETC systems ranging from a more basic locomotive-based implementation up to a full vital moving block system. Assessment of the incident prevention capabilities of a range of ETC systems provides maximum value from the analytical exercise.

Rather than focusing on specific systems currently under development, where full access to functionality and design parameters might not be feasible or ongoing functionality changes might change the validity of the analysis results, the decision was made to develop a generic hierarchy of ETC systems (Table 1-3). The one exception to the generic system approach was the inclusion of an ETC system that closely paralleled the functionality of the US PTC system mandated for implementation.

Table 1-3. High-level hierarchy of ETC systems.

ETC Level 1	ETC Level 2	ETC Level 3	ETC Level 4
Crew assist and monitoring	Crew assist and enforcement	Vital enforcement (US PTC system)	Vital enforcement and moving block
Locomotive equipment only	Locomotive equipment and selective wayside buildouts	Locomotive equipment and full wayside buildouts	Locomotive equipment and wayside equipment
Overlay on existing train control system	Overlay on existing train control system	Overlay on existing train control system	Full replacement of existing train control system
Crew warnings	Non-vital enforcement of warnings	Vital enforcement of warnings	Vital enforcement of warnings
Basic on-board display: • Track diagram • Operating authority	Improved display: • Key switch position • Operating authorities • Operating restrictions	Full display: • All track conditions • All switch positions • Operating authorities • Foreman's authorities	Full operating display incorporating all track conditions, operating authorities, and restrictions
Control office reporting of warnings	Crew warning prior to enforcement and control office reporting of warnings and enforcements	Crew warning prior to enforcement and control office reporting of warnings and enforcements	Crew warning prior to enforcement and control office reporting of warnings and enforcements

2.3 ETC Functionality – Key Parameters

Working with a hierarchy of generic ETC systems requires that system functionality be well determined before initiating the analysis. This prevents functionality changing during the analysis and negatively impacting the validity of the results. The first step in this process was to define a set of key parameters to help define the functionality of the ETC systems under review. To keep the preventability analysis aligned with the ongoing PTC implementation in the US, the key functionalities identified by the US PTC initiative were used. These include:

- Prevention of over speed derailments;
- Prevention of train to train collisions;
- Prevention of trains occupying improperly aligned switches; and
- Prevention of trains entering a foreman's work authority limits.

2.4 ETC Systems Description

The following section provides a more detailed overview of each of the ETC systems included in this analysis. The intent of these descriptions is to provide a better general understanding of the composition and operation of each of the proposed systems. They are not intended to provide a detailed technical description of all facets of any of the proposed ETC systems.

2.4.1. ETC Level 1

The Level 1 ETC system is primarily a crew assist and monitoring system and is intended to be the most basic of the systems analyzed. This system is envisioned to be locomotive-centric and minimally invasive on existing infrastructure, with equipment installed only on-board the locomotive and in the centralized dispatch office. The system is expected to make use of commercially available communications facilities and therefore not be reliant on continuous real-time connectivity with the central office.

Key components of this system include:

Locomotive: on-board computer, basic crew display monitor, GPS location system, crew alert system, and cellular/satellite communications equipment

Dispatch office: office ETC Computer, interface to office computer assisted dispatch (CAD) system, rail traffic controller display, and communication interface equipment

Wayside: No wayside equipment installation

Figure 1-2 depicts the ETC Level 1 system.

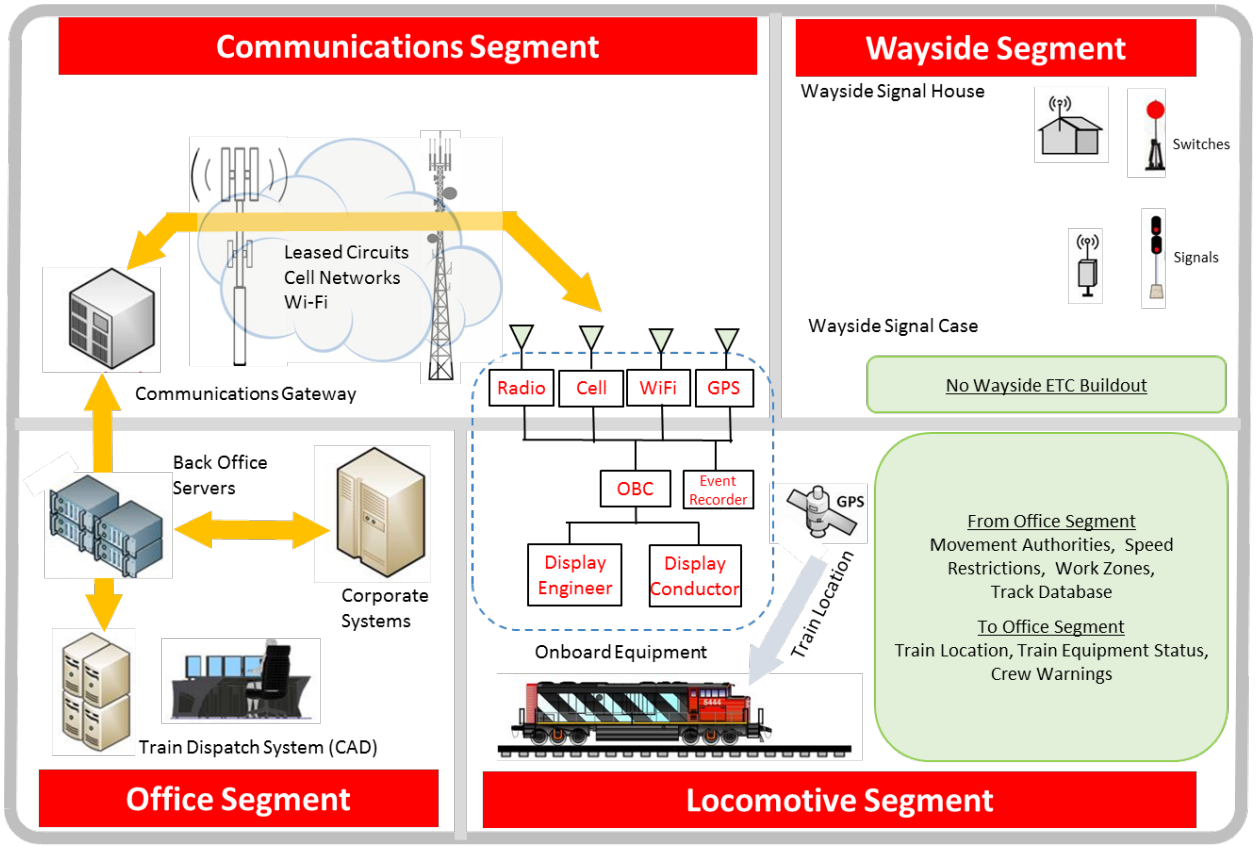

Figure 1-2. Level 1 ETC system.

In the Level 1 ETC system implementation, the train control CAD computer system provides the following information to the office ETC computer system:

- Copies of all operating authorities and signal aspect information;
- Details of all slow orders and speed restrictions; and
- Copies of all foremen's authorities (work authorities and occupancy authorities).

The ETC office computer adds GPS information and packages the information for delivery to specific locomotives based on locomotive number and train ID information. This information is then passed on to the communication interface equipment for transmission to the locomotive in the field.

The locomotive on-board computer incorporates a track infrastructure database that is used to generate a basic track display to the operating crew along with the appropriate operating authority limits and speed restrictions. The display also shows current train location and speed

information. The on-board computer monitors train speed and location and compares this information to the operating authority and speed limit information and provides a warning (audible or visual or both) to the crew when appropriate.

The Level 1 ETC system also provides updates to the train control dispatch office on current train position, any crew warnings generated, and any occurrences when the train exceeded speed limits or authority restrictions.

The Level 1 ETC system provides crew warnings to prevent incidents for the following types of occurrences:

- Warnings on approach to limits of operating authorities;
- Warnings on approach to red (stop) signal;
- Warnings on approach to maximum track speed or when approaching restricted speed limits;
- Warnings for speed restrictions based on locomotive position only (system would not have train length information to protect speed restrictions for entire train); and
- Warnings when approaching foreman's authorized limits.

Note that because no wayside buildouts are envisioned with the Level 1 ETC system, there is no ability to protect against train movements through a misaligned switch.

2.4.2 ETC Level 2

The Level 2 ETC system is envisioned as an intermediate ETC implementation that builds on the basic functionality provided by the Level 1 system without the complexity of the Level 3 system (which is modeled after the US PTC implementation). The Level 2 system is also primarily locomotive-centric but adds the ability to include selective wayside equipment installation at key switches or controlled signal locations. Adding wayside equipment introduces the ability to detect positions of key switches and thereby prevent train movements through these equipped locations.

In addition to selective wayside equipment, the Level 2 system also incorporates a locomotive brake interface that allows the system to implement enforcement actions to prevent occurrences

rather than simply warning the crew. Thus, the Level 2 system acts as a crew assist and enforcement system rather than a crew assist and monitoring system (e.g., Level 1).

Similar to the Level 1 system, the Level 2 system is intended to use commercially available communication facilities (cellular or satellite) whenever possible. The inclusion of the enforcement functionality and the equipping of wayside locations will require more robust communication reliability than the Level 1 system, which in some instances may require construction of dedicated communications facilities.

Key components of this system include:

Locomotive: on-board computer, improved interactive crew display monitor, more accurate GPS location system (track discrimination), crew alert system, locomotive brake interface, and cellular/satellite communications equipment

Dispatch office: office ETC computer, interface to office CAD system, rail traffic controller display, and communication interface equipment

Selective wayside buildouts: wayside interface units (monitor switch positions, signal aspects, etc.) and communications equipment (cellular/satellite/data radio)

Figure 1-3 depicts the ETC Level 2 system.

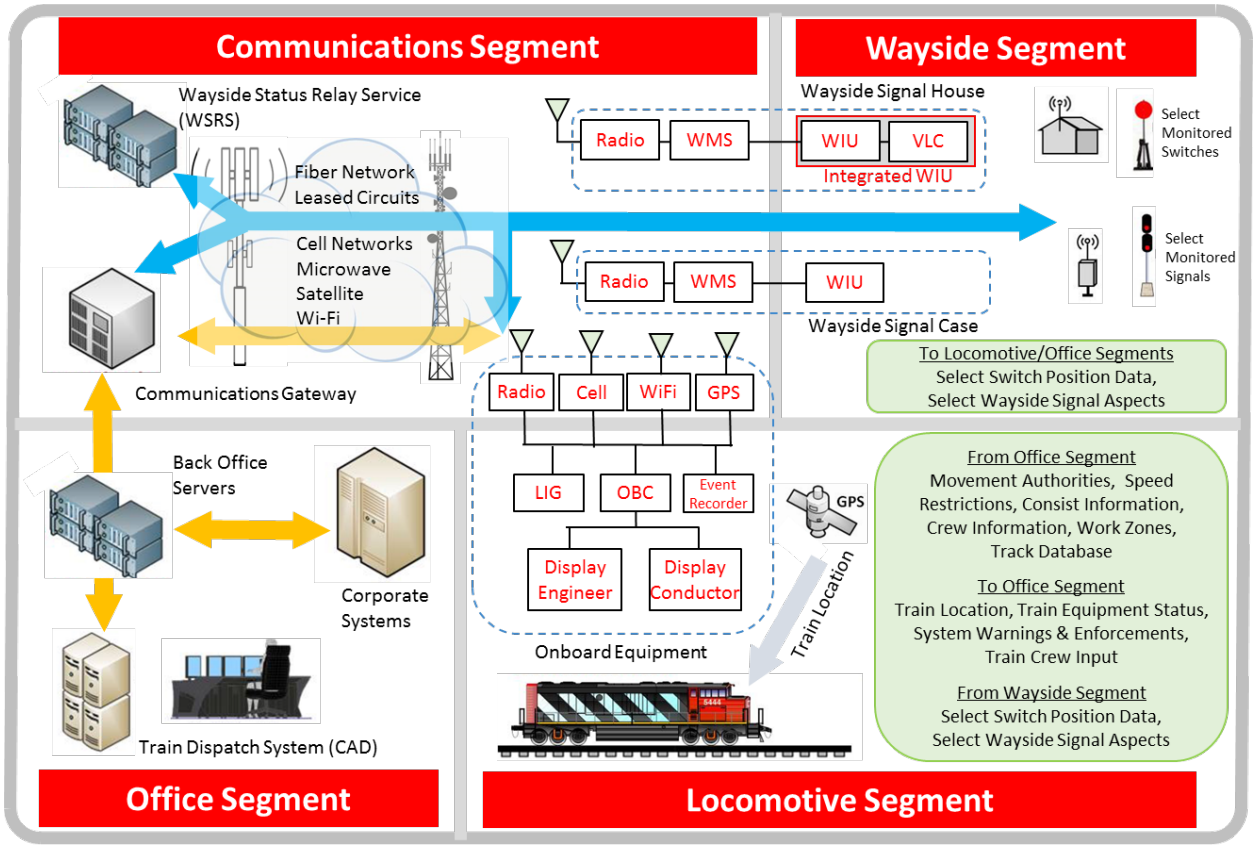

Figure 1-3. Level 2 ETC system.

In the Level 2 ETC system implementation, the office CAD provides the following information to the ETC office computer:

- Copies of all operating authorities and signal aspect information;
- Details of all slow orders and speed restrictions;
- Copies of all foremen's authorities (work authorities and occupancy permits);
- Information on all switch positions; and
- Train routing information.

The ETC office computer adds GPS information and packages the information for delivery to specific locomotives based on locomotive number and train ID information. This information is then passed on to the communication interface equipment for transmission to the locomotive in the field.

The locomotive on-board computer incorporates a more detailed track database, including all switch and signal location information, and this is used to generate a higher resolution track display for the operating crew. The on-board computer updates the display with signal and switch information as it is received from the office computers and, in addition, can display the locations of speed restrictions and foreman's authorities. The on-board computer monitors crew operation of the train and provide a warning to the crew when potential violations of operating authorities are detected. If the crew does not take appropriate measures to prevent the operating violation from occurring, then the ETC on-board computer initiates train braking to bring the movement to a stop.

The Level 2 system tracks and reports all crew warning conditions and ETC initiated braking activities to the central ETC computer.

The Level 2 ETC system is able to provide crew warnings to prevent incidents for the following types of occurrences:

- Warn then enforce stop on approach to limits of operating authorities;
- Warn then enforce stop on approach to red (stop) signal;
- Warn then enforce stop on approach to maximum track speed or when approaching restricted speed limits;
- Warnings and enforcement for speed restrictions can be head end and full train (system allows crew to enter train length information to protect speed restrictions for entire train);
- Warn then enforce stop when approaching foreman's authorized limits; and
- Warn then enforce stop for misaligned switch (for equipped switches).

2.4.3 ETC Level 3

The Level 3 ETC system is intended to closely parallel the functionality and operation of the systems currently being implemented by the rail industry in the US in response to the Railway Safety Improvement Act. The Level 3 ETC system includes many of the same types of components as the Level 2 ETC system but with a significant number of key enhancements that enable vital enforcement of operating authorities, including:

- Locomotive on-board computer with high reliability/high resolution display and fail-safe brake system interface;
- Dispatch office CAD system interface for authority translation, verification, and validation;
- Wayside interface units at all mainline switches, controlled signals, and intermediate signals as well as track circuits; and
- High reliability communication link between locomotive and office as well as field and office.

From a functionality perspective, the ETC Level 3 system provides the following enhancements over Level 2:

- Full in-cab display of all track infrastructure (all signals and all switches);
- Full in-cab display of all operating authorities and all operating restrictions (including emergent conditions);
- Positive confirmation of reception of authorities and restrictions (back to office ETC);
- Full in-cab display of all routing information; and
- Vital enforcement of operating restrictions, authorities, work zones, speed restrictions, switch alignment, and turnout speeds.

Figure 1-4 depicts the ETC Level 3 system.

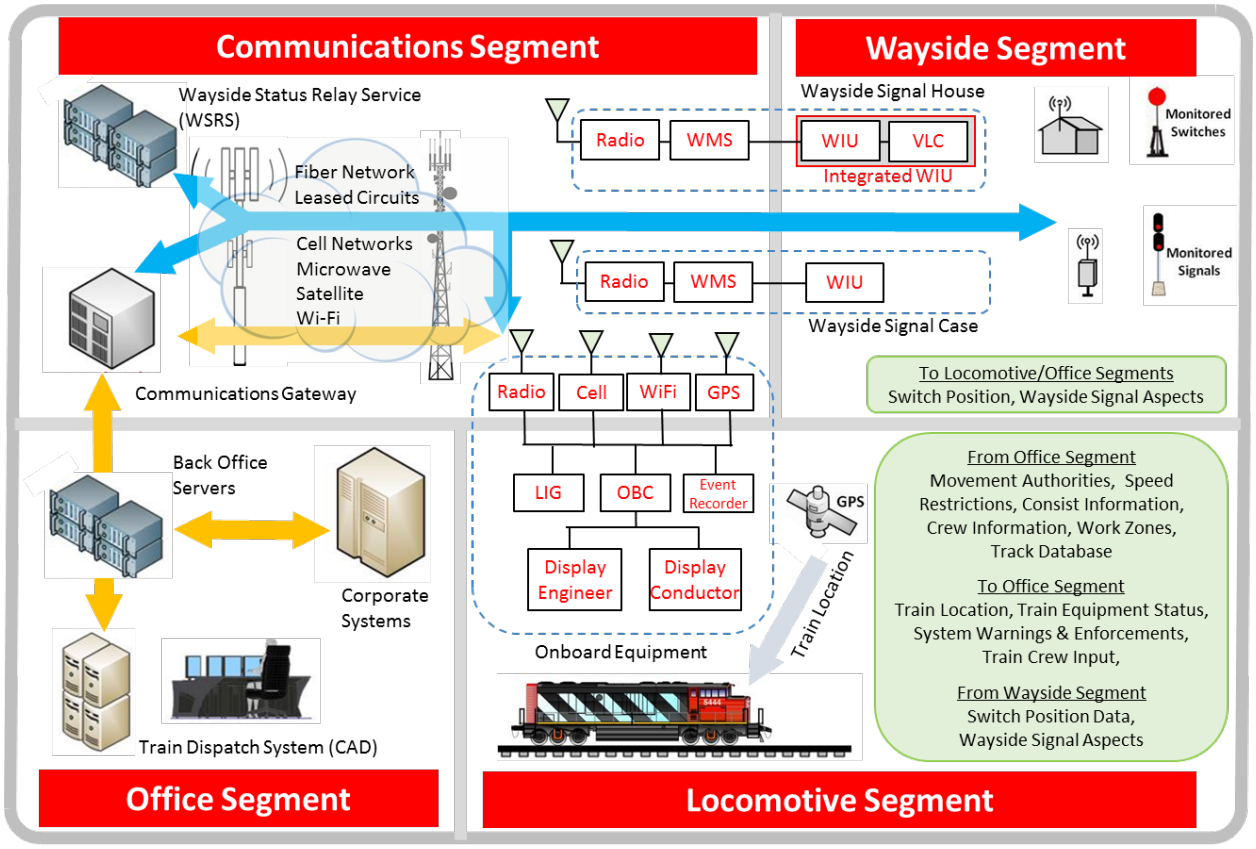

Figure 1-4. Level 3 ETC System.

The Level 3 ETC system is able to provide crew warnings and then enforce braking to prevent incidents for the following types of occurrences:

- Warn then enforce stop on approach to limits of operating authorities;
- Warn then enforce stop on approach to red (stop) signal;
- Warn then enforce all wayside signal aspects;
- Warn then enforce stop on approach to maximum track speed or when approaching restricted speed limits;
- Warnings and enforcement for speed restrictions can be head end and full train (system allows crew to enter train length information to protect speed restrictions for entire train);
- Warn then enforce stop when approaching foreman's authorized limits;
- Warn then enforce maximum speed (entered by crew) through established work zones;
- Warn then enforce restricted speed; and
- Warn then enforce stop for misaligned switch (for all switches).

2.4.4 ETC Level 4

The Level 4 ETC system is a fully communication-based moving block train control system that replaces the existing train control system. The Level 4 system requires a number of key infrastructure enhancements over the Level 3 system. These include:

- Vital position determination system on-board the locomotive;
- Vital on-board display of digital operating authorities and cab signal information;
- Detailed real-time train consist updates to enable positive rear end train protection;
- Engineering field data terminals with data communications to locomotive on-board and office computers; and
- Continuous high-speed data communications.

Implementation of a Level 4 ETC system will enable the following functionality enhancements:

- Full communications-based train control with moving block technology;
- Elimination of the requirement for wayside signalling equipment;
- Interactive on-board display provides full consist operating authority (no paper forms and no verbal transmission of authorities);
- Warning and enforcement of all operating restrictions, speed restrictions, train routing, and engineering authority protection; and
- Possibility to interface with wayside hazardous warning devices, railway crossing warning devices, and other intelligent transportation system devices.

Figure 1-5 depicts the ETC Level 4 system.

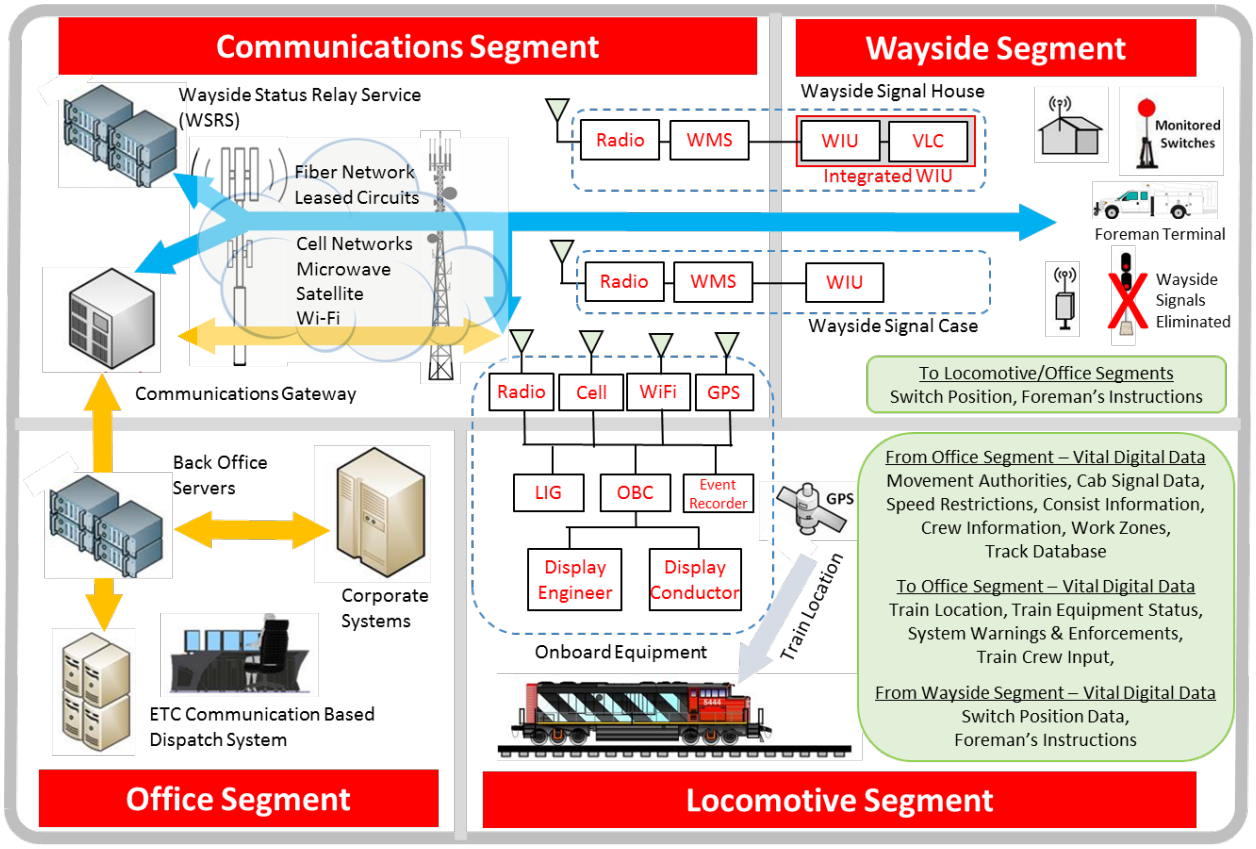

Figure 1-5. Level 4 ETC system.

The Level 4 ETC system is able to provide crew warnings and then enforce braking to prevent incidents for the following types of occurrences:

- Warn then enforce stop on approach to limits of operating authorities;
- Warn then enforce stop on approach to red (stop) signal;
- Warn then enforce all wayside signal aspects;
- Warn then enforce stop on approach to maximum track speed or when approaching restricted speed limits;
- Warnings and enforcement for speed restrictions can be head end and full train (system allows crew to enter train length information to protect speed restrictions for entire train);
- Warn then enforce stop when approaching foreman's authorized limits;
- Warn then enforce maximum speed (digital entry by foreman) through established work zones;
- Warn then enforce restricted speed;

- Warn then enforce stop for misaligned switch (for all switches); and
- Warn then enforce stop to provide positive rear end train protection.

2.5 ETC Levels Summary

Based on the system descriptions and functionality assessments, incident prevention abilities clearly increase from the basic Level 1 system to the highly complex Level 4 system. Analysis of the four differing ETC systems enables a determination of the relative benefits of increasing complexity from the perspective of reducing ETC-preventable incidents. This information in conjunction with an assessment of key causes of ETC-preventable occurrences enables determination of the best fit of an ETC system for any given rail corridor.

Table 1-4 summarizes the functionality comparison of the four levels of ETC systems considered in this occurrence prevention analysis.

Table 1-4. Functionality comparison of ETC systems.

ETC Level 1 Crew Assist & Monitoring Locomotive Equipment Only	ETC Level 2 Crew Assist & Enforcement with Selective Wayside Buildouts	ETC Level 3 US PTC System Vital Overlay with Full Wayside Buildouts	ETC Level 4 Vital Moving Block System Train Control Replacement
			Vital enforcement
			Digital foreman's terminals
			Incorporation of all operating authorities (incl. TGBO, DOB, etc.)
			Confirm and validate all releases of operating authority
		Vital enforcement	Positive rear end train protection
	Non-vital enforcement	Unauthorized reverse movements	Unauthorized reverse movements
Warnings to crew	Correct switch alignment - selective switches only	Correct alignment of all switches	Correct alignment of all switches
Accurate train location information	Accurate train location information	Accurate train location information	Accurate train location information
Speed restrictions - head end only	Speed restrictions - head end only	Speed restrictions - head end & full consist	Speed restrictions - head end & full consist
Track speed limit	Track speed limit	Track speed limit	Track speed limit
Entry into foreman's track authorities	Entry into foreman's track authorities	Entry into foreman's track authorities	Entry into foreman's track authorities
Entry into established work zones	Entry into established work zones	Entry into established work zones	Entry into established work zones
Operating authority restrictions	Operating authority restrictions	Operating authority restrictions	Operating authority restrictions
Operating authority limits	Operating authority limits	Operating authority limits	Operating authority limits
Unauthorized entry onto main track	Unauthorized entry onto main track	Unauthorized entry onto main track	Unauthorized entry onto main track
	Locomotive and train ID validation against operating authorities	Locomotive and train ID validation against operating authorities	Locomotive and train ID validation against operating authorities
	After arrival train authority	After arrival train authority	After arrival train authority
	Signal aspect enforcement - selective signals only	Signal aspect enforcement - all signals	Enable elimination of wayside signals

*Note: Functionality is theoretical for analysis purposes but is based on typical systems implemented or under development

3 Developing a Database of Railway Occurrences

3.1 The TSB RODS Database

The primary source of the railway occurrence information used in this study is the national Railway Occurrence Database System (RODS) maintained by the TSB. An occurrence, as defined by the TSB, is *"any accident or incident associated with the operation of rolling stock on a railway, and any situation or condition that the Board has reasonable grounds to believe could, if left unattended, induce an accident or incident"* (TSB, 2016) [accessed: 2017-07-17, last updated: 2016-07-19, www.tsb.gc.ca/eng/stats/rail/2015/sser-ssro-2015.asp].

A selection of situations that constitute a railway 'accident' or 'incident' include:

- when a person is either killed or sustains a serious injury after coming into contact with rolling stock;
- when the rolling stock or its contents are involved in a collision or derailment;
- when an unprotected main-track switch is left in an abnormal position;
- when there is an unplanned or uncontrolled movement of rolling stock; or
- when rolling stock passes a signal indicating stop in contravention of the Canadian Rail Operating Rules (CROR).

A detailed list of all situations defining an 'accident' or 'incident' can be found in Part 1 of the Transportation Safety Board Regulations (SOR/2014-37). In these situations, a report must be submitted to the TSB by someone with direct knowledge of the occurrence, be it either the operator of the rolling stock, the operator of the track, or a crew member. Additionally, any other party with knowledge of the railway occurrence (outside of those for which reporting is mandatory) can provide relevant information voluntarily. All information reported to the TSB is then used to characterize the occurrence and is compiled in the RODS database.

On the 15th of each month, the TSB publishes data on railway occurrences that have occurred between January 2004 and the end of the preceding month. However, only a select subset of the information regarding each individual occurrence is publically released. This public domain RODS information was used by the WG in their analysis. To perform a more detailed assessment of all RODS occurrences, a more detailed dataset was requested by CaRRL and provided by the

TSB. CaRRL received an extracted version of the RODS database in spring 2017, which covers the time period from January 2, 2000 to May 1, 2017 and contains 26,685 individual occurrences. As the main RODS database itself is continually being updated by the TSB, the version extracted and provided to CaRRL in spring 2017 is subject to the accuracy of the database at the time. There may be occurrences from between 2000 and 2017 that had yet to be integrated into RODS and therefore will not be included in this analysis.

Each occurrence entry in RODS contains information including (but not limited to) the date, time, and subdivision on which the occurrence occurred, an occurrence type classification, primary and contributing factors that led to the occurrence, and an initial summary of the occurrence. General data quality is relatively consistent throughout the period from January 2, 2000 to May 1, 2017, with the sole exception being the initial summary entries. Due to the relative variance in the descriptive quality of initial incident summaries prior to 2007, CaRRL was not able to as conclusively assess the ETC preventability of occurrences from January 2, 2000 to December 31, 2006. For this reason, the decision was made to focus the ETC preventability analysis on occurrences between January 1, 2007 and December 31, 2016. The remainder of this report and subsequent analyses focus on occurrences within this ten-year time period.

An occurrence descriptor that is not immediately evident within RODS is a differentiation between occurrences involving passenger train operations and those involving freight operations. While it may be possible to identify passenger- and freight-related occurrences through a detailed analysis of the individual occurrence descriptions, this was considered beyond the scope of this analysis.

There are 22 different types of occurrences in RODS related to the different situations in which the TSB requires a report be submitted. The ETC WG based their breakdown of the RODS dataset and subsequent analysis on these 22 incident types and, to maintain consistency, the same has been done for this analysis. Table 1-5 lists the 22 different types of occurrences in RODS as well as the annual numbers and total for the period from January 1, 2007 to December 31, 2016 (14,036 in total). Table 1-5 shows non-main-track train accidents (derailments and collisions)

account for slightly more than half (50.4%) of the occurrences from 2007-2016, while main-track train accidents (derailments and collisions) account for 7.3%.

Table 1-5. Summary of the RODS occurrences between January 1, 2007 and December 31, 2016.

Incident Type	Year										Total
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Crossing	235	234	199	187	183	194	187	191	171	131	1912
Fire	25	13	20	30	23	17	10	36	32	35	241
Historical	0	0	0	0	0	0	0	0	0	0	0
Crew Member Incapacitated	1	2	0	1	0	1	6	2	2	1	16
Track Unit Derailment	3	5	20	11	10	7	18	14	21	20	129
Track Unit Collision	30	22	30	23	23	17	23	21	32	14	235
Main-Track Train Derailment	164	132	68	89	105	71	90	105	78	62	964
Main-Track Train Collision	10	7	5	4	3	6	4	9	4	2	54
Non-Main-Track Train Derailment	785	663	550	595	528	539	543	662	687	539	6091
Non-Main-Track Train Collision	111	97	99	95	91	106	95	114	96	74	978
Movement Exceeds Limits of Authority	106	111	108	101	119	121	98	129	143	132	1168
Main-Track Switch in Abnormal Position	8	15	6	5	10	6	7	7	12	6	82
Trespasser	103	75	75	84	67	75	57	55	50	70	711
Employee	16	11	12	9	10	6	8	10	9	10	101
R/S* Collision with Object	4	6	15	3	18	19	32	31	31	51	210
R/S* Collision with Abandoned Vehicle	13	15	10	9	4	8	10	3	11	11	94
R/S* Damage without Derailment or Collision	12	16	13	11	20	8	23	13	20	13	149
Runaway R/S*	14	16	13	5	16	13	13	12	14	7	123
Unprotected Overlap of Authorities	8	7	7	5	7	5	4	5	6	4	58
Signal Less Restrictive than Required	0	3	1	4	3	1	1	2	5	1	21
Explosion	0	0	0	0	0	0	0	0	0	0	0
DG** Leaker	88	66	80	70	81	93	93	64	33	31	699

* R/S: Rolling stock, ** DG: Dangerous Goods

3.2 Supplementation of the RODS Database

When assessing individual occurrences in RODS to determine ETC preventability, the most useful information will be obtained from the initial summary as well as the primary and contributing factors included with each entry. For a number of main-track train derailments, however, beyond the basic information (train numbers and lengths) the initial summaries predominantly contain only the results of each derailment (descriptions of the rolling stock that derailed and what was being carried). Little information is provided on the causal factors related to each derailment. Furthermore, the primary and contributing factor entries can be left blank if not known at the time of reporting. For such occurrences, determining whether they would have been preventable had an ETC system been installed was more challenging.

As main-track train derailments represent a high visibility category of railway occurrences, it is critical to have the most accurate information regarding each occurrence to produce the most reliable ETC preventability assessment. To this end, two additional data sources were used to supplement the information found in RODS when required: the data used to generate the TSB table summarizing assigned factors for main-track train derailments (2007-2016) (TSB Table 4b – www.tsb.gc.ca/eng/stats/rail/2016/sser-ssro-2016-tbis.asp) and the reports generated for each TSB investigated railway occurrence (2000-2016). Table 1-6 is a reproduction of TSB Table 4b as it appeared on the TSB website on July 20, 2017.

Additional assigned factors for individual main-track train derailments beyond what is contained within RODS were identified by comparing the number of assigned factors in the RODS database with those in TSB Table 4b for a given year. RODS had consistently less assigned factors than TSB Table 4b (Table 1-6). By itself, TSB Table 4b could not be used to perform an occurrence-by-occurrence ETC preventability assessment as it does not provide information on which assigned factors relate to a specific occurrence. Therefore, this information was requested by CaRRL and provided by the TSB. Assigned factors from TSB Table 4b (Table 1-6) were not cross-referenced with the information in RODS for every main-track train derailment. Cross-referencing was only performed when a reliable ETC preventability assessment could not be made based solely on the information provided in RODS. One limitation of TSB Table 4b (Table 1-6) is that it only contains federally reportable main-track train derailments. Derailments

involving provincial rail operators are not federally required to be reported (but still can be) and therefore are not consistently included in TSB Table 4b.

Table 1-6. Reproduction of the assigned factors for main-track train derailments table maintained by the TSB (TSB Table 4b).

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total number of assigned factors	**182**	**153**	**81**	**91**	**126**	**68**	**95**	**111**	**82**	**67**
Environmental	17	12	6	1	6	4	5	11	3	4
Equipment	61	42	23	27	48	19	33	27	23	21
Axle	14	11	5	7	11	6	8	4	6	6
Brakes	8	3	6	3	7	3	3	4	4	5
Draft system	10	4	4	4	4	4	2	5	5	1
Superstructure	8	5	0	2	3	2	7	3	1	3
Truck	5	5	1	5	7	2	5	6	2	1
Wheel	16	12	7	6	16	2	8	5	5	5
Track	59	62	34	33	45	28	30	49	32	17
Geometry	25	23	12	16	18	14	10	11	8	7
Object on track	1	1	1	2	2	0	2	1	0	0
Other track material	2	6	5	2	4	2	0	7	2	1
Rail	18	27	7	7	12	8	12	17	11	4
Roadbed	3	4	5	2	6	4	4	5	7	2
Switch	0	1	2	2	1	0	0	6	1	3
Turnouts	6	0	0	1	1	0	1	0	0	0
Actions	20	20	10	24	19	15	25	18	16	20
Failure to protect	4	8	3	2	5	5	5	4	3	5
Failure to secure	0	0	1	0	0	1	1	0	0	0
Failure to use equipment properly	6	6	5	10	7	2	9	6	6	9
Improper loading/lifting	3	1	1	3	0	2	2	3	2	1
Improper placement/position for task	2	1	0	4	2	2	6	3	1	4
Inadequate/inappropriate maintenance of equipment	1	3	0	1	1	0	0	0	1	0
Operating at improper speed	1	1	0	3	3	2	2	2	3	0
Vandalism	2	0	0	0	0	0	0	0	0	1
Other actions	1	0	0	1	1	1	0	0	0	0
Other assigned factors	25	17	8	6	8	2	2	6	8	5
Derailments by number of assigned factors	**160**	**129**	**67**	**82**	**110**	**67**	**84**	**102**	**77**	**63**
One factor assigned	146	117	58	74	98	66	73	95	72	55
More than one factor assigned	12	12	9	7	12	1	10	6	4	5
No factor assigned	2	0	0	1	0	0	1	0	1	3

Individual reports prepared by TSB investigators in response to specific railway occurrences represent the most detailed information on those occurrences, even beyond what is included in RODS. Of interest to this ETC assessment are the specific findings into the cause of each

investigated occurrence. These reports are publically available from the TSB website; from 2000 and 2016, the TSB produced reports for 240 separate occurrences (an average of approximately 14 reports per year). The majority of the TSB reports are related to main-track train derailments; however, reports were also prepared following a variety of other occurrences including main-track train collisions, crossing incidents, and MELA incidents, amongst others. Where available, the ETC preventability assessment was performed using the information contained in the TSB investigation reports, regardless of the type of occurrence.

4 ETC Assessment of the RODS Database and Associated Assumptions

4.1 Assumptions

Applying the proposed hierarchical ETC functionality to occurrences in the RODS database required making assumptions with regards to how the ETC system would both be installed and implemented. Prior to starting the assessment of the RODS datasets, an initial set of assumptions was made based on knowledge of how the US PTC system and the proposed hierarchical ETC system operate (Table 1-7). This was the followed by a second, more specific, set of assumptions (Table 1-8) that were required to address various occurrences in the RODS database where ETC preventability could not be accurately assessed based on the initial set of ETC system assumptions. Both sets of assumptions are critical to the results of the ETC assessment as different assumptions would have yielded slightly different results. This subsection is dedicated to outlining and justifying the assumptions made by CaRRL during the ETC assessment of the 2007-2016 RODS dataset.

4.1.1 Track Type

ETC track type assumptions relate to the type of track where the ETC system would be installed. Based on the US PTC rollout as well as other risk factors (train speeds) and economic considerations, CaRRL assumed that ETC systems would only be installed on mainline track. For the purposes of this analysis, mainline track was considered to be all main track and station track. Station track was considered as mainline track due to the high density of commuters. Other track types, including yard tracks, back tracks, wye tracks, and track within cautionary limits were not considered as mainline track and therefore not equipped with ETC systems.

4.1.2 Railway Equipment

ETC railway equipment assumptions are related to the types of rail vehicles that either would or would not be equipped with ETC systems. All mainline locomotives were assumed to be ETC equipped while yard assignments would not have any ETC systems installed. As belt pack assignments are primarily yard assignments, they too would not have had any ETC systems installed. Furthermore, as ETC systems are primarily locomotive-centric systems, rolling stock without locomotives (individual cars or cuts of cars) were assumed to not have any associated on-board ETC system. Finally, ETC systems would also not have been installed on engineering

equipment including, but not limited to, hi-rails, track equipment (grinders), and work equipment (cranes).

Table 1-7. Initial ETC system assumptions.

Initial Assumption Groups	Specific Assumptions
1) Track Type	• ETC installed on all main track • ETC not installed on yard track • ETC not installed on back track • ETC not installed within cautionary limits • ETC installed on station track
2) Railway Equipment	• ETC installed on all mainline locomotives • ETC not installed on yard assignments • ETC not installed on belt pack assignments • ETC not installed on rolling stock without locomotives • ETC not installed on engineering equipment (hi-rails, grinders, work equipment)
3) Foreign Objects	• Vehicles (abandoned or otherwise) entering the railway right-of-way (ROW) would not be ETC equipped and not protected • Trespassers in the ROW are not ETC protected
4) Train Movements	• ETC system enabled for all equipped trains travelling on the mainline • ETC system disabled during switching moves • ETC system disabled when travelling on non-main track • ETC system disabled during work train operation besides travelling to the work area • ETC system enabled during light engine moves
5) System Intervention Thresholds	• Threshold for entry into a foreman's authority is *zero* • Threshold for exceeding authority limits (occupancy control system (OCS) or signal) is *zero* • Threshold for exceedance of posted speed is *4* mph (*6.44* km/h)

4.1.3 Foreign Objects

ETC foreign objects assumptions are related to public vehicles or persons on the right-of-way (ROW) that the ETC system would not be able to protect against. It was assumed that the ETC system would not be able to protect against vehicles entering the ROW at public crossings or abandoned vehicles left foul of the track. In addition to vehicles, the ETC system would also not be able to protect against trespassers entering the ROW.

4.1.4 Train Movements

A critical set of assumptions was related to the types of train movements where the ETC system would be disabled. The ETC system was envisioned as a crew-assistance or fail-safe overlay (depending on ETC Level) for use only during normal train operations. A large increase in

system complexity would accompany adapting the ETC system to specialized train movements. Furthermore, the potential for major incidents during these types of train movements is not as large as during normal mainline train operations. A similar rationale against the inclusion of special train movements has been included in the US PTC system. As such, during specific movements an ETC-equipped train may have the ETC system disabled, including:

- Train movements on non-main track: ETC is assumed to be installed only on main track and therefore ETC equipped trains will have the ETC system disabled while traversing non-main track;
- Switching moves: ETC systems are designed to enforce the existing train control system and associated operating authorities. When making a switching movement, the train consist is normally not maintained as a single entity and back and forth locomotive movements are made under the control of the operating train crew. The large variability in types of movements that may be required while switching make it virtually impossible for the ETC system to be operational, especially as the ETC system is designed to prevent contact between rail cars while switching necessitates such contact. For this reason, ETC-equipped trains are assumed to have their ETC system disabled while making switching movements;
- Work train activities: Work-train locomotives may be ETC-equipped and it was assumed that the system would be enabled when the work train was travelling to and from the work site. Train movements at the work site are normally low speed with repeated back and forth operations under the local direction of a foreman or supervisor; therefore, the ETC system is assumed to be disabled while at the work site or when travelling on non-main track; and
- Light engine movements: The on-board ETC system was assumed to be enabled during light engine movements when the locomotives were ETC-equipped and travelling along main track.

4.1.5 System Intervention Thresholds

Also important was defining three thresholds when the ETC system would intervene should that be required. A major function of the proposed ETC system would be to not allow any un-authorized entry into an engineering track occupancy permit (TOP) or established work zone, so

the ETC distance threshold for entry into a foreman's authority was assumed to be zero. The second assumed threshold was a zero tolerance threshold for trains passing signals indicating stop or exceeding their authority limits. The final threshold assumption was related to the difference between actual train speed and posted train speed (be it a restricted train speed limit, track speed limit, or signal speed limit) at which the ETC system would intervene. For the purposes of this assessment, this speed difference threshold was set at 4 mph (6.44 km/h). This slight overspeed threshold is similar to that incorporated in the US PTC system to prevent the system from applying the brakes and stopping the train in case of instantaneous or momentary speed limit exceedances before they can be addressed by the crew. Furthermore, as the number of occurrences where the 4 mph threshold was a key consideration was small, the adoption of a 0 mph threshold assumption would result in only very minor differences in the overall results.

As the assessment of the RODS dataset progressed, it became evident that additional assumptions would be required to accurately describe why certain occurrences were or were not ETC preventable. These ETC functionality assumptions are summarized in Table 1-8 based on the major incident type categories in which they were predominantly required. However, these assumptions were also applied to occurrences in other incident type categories as necessary. While the first set of assumptions (Table 1-7) describe where and when the ETC system would be applied, the ETC functionality assumptions in Table 1-8 are related to how the ETC system is designed to work in specific circumstances.

Table 1-8. ETC functionality assumptions.

Major Incident Type where Applicable	Specific Assumptions
1) Main-Track Train Derailments	• ETC will not prevent mechanical equipment failure caused incidents • ETC will not prevent hot bearing related incidents • ETC will not prevent broken/damaged wheel related incidents • ETC will not prevent track geometry related incidents • ETC will not prevent broken rail related incidents • ETC will not prevent brake valve failure related incidents • ETC will not prevent train handling related incidents • ETC will not prevent train marshalling related incidents • ETC will not prevent occurrences caused by high wind conditions • ETC will not prevent landslide, avalanche, or washout related incidents • ETC will not prevent track failure related incidents • ETC will not prevent derailments caused by emergency break applications • ETC will not prevent incidents caused by ice and snow or mud buildup on track
2) DG Leaker	• ETC will not prevent cars leaking dangerous goods incidents
3) Fire	• ETC will not prevent incidents involving fires when in compliance with all operating restrictions
4) Crew Member Incapacitated	• ETC will not prevent occurrences related to crew member incapacitation
5) Employee	• ETC will not prevent occurrences involving injuries to employees when in compliance with all operating authorities
6) MELA	• ETC cannot protect against track condition changes in front of the train • ETC will not protect rear of train from slack running out • ETC will protect against entry into established work zones (Rule 42, etc.) and foreman's authority limits (TOP)
7) Unprotected Overlap of Authorities	• ETC cannot protect against human errors (relaying information to and from a foreman, rail traffic controller (RTC) issues when issuing, removing or changing track protection)

4.1.6 Main-Track Train Derailments

Main-track train derailments can occur as a result of a number of different causal factors. When determining ETC preventability, CaRRL evaluated the functionality incorporated into each of the four ETC Levels to determine their ability to detect and take preventative actions in regards to the root cause of each derailment incident. Key considerations when performing the preventability analysis included:

1. ETC Level 1, 2 and 3 are overlays on existing train control technologies and do not replace the existing train control system,
2. ETC, as defined for this analysis, does not include additional hazard or defect detection capabilities, and

3. ETC, as defined for this analysis, does not include interfaces to existing hazard and defect detection systems.

In this analysis, the functionality definitions for the four Levels of the ETC hierarchy closely parallel other ETC systems either being installed or under development. There is no built-in ability to detect or prevent incidents that result from a number of emergent mechanical, environmental or operational conditions. These include:

- Mechanical: broken rails, broken or defective wheels, air brake system failures,
- Environmental: high wind incidents, landslides, washouts etc,
- Operational: train marshalling, train handling (when operating within existing authority and speed limits).

Broken rail-related main-track train derailments are a special case that requires additional clarification. Existing control systems for Canadian rail lines equipped with track circuits are typically either ABS (Automatic Block Signal) or CTC (Centralized Traffic Control), while those without track circuits are governed by OCS (Occupancy Control System). Each of these are examined from a ETC preventability of broken rail-related main-track train derailments perspective below:

a) CTC or ABS track: An existing broken rail on CTC or ABS track will, in most cases, be detected by the track circuit and result in the signals governing movement over that section of track to display a Stop aspect. Therefore, in CTC and ABS, the existing train control system already protects against broken rails that occur before train arrival and ETC provides no additional protection. Rail breaks that occur under a train are not detectable by either CTC or ABS and therefore ETC provides no additional protection.
b) OCS track: In OCS track there are no track circuits so there is no existing broken rail detection capability. Implementation of any of the proposed four Levels of the ETC system does not include installation of track circuits so even when installed ETC will not provide any additional broken rail protection.

4.1.7 Fire, Crew Member Incapacitated, and Employee-related Occurrences

The described ETC systems would focus on preventing incidents when the train exceeds its operating authorities, speed restrictions, or approaches a misaligned switch. It was assumed that the system would not prevent any incident that occurred while the train was in compliance with all operating restrictions. As such, fire, crew member incapacitated, and employee-related occurrences would not be preventable as long as the train remained compliant with its operating authorities.

4.1.8 Unprotected Overlap of Authorities

At Level 3, the ETC system would operate as a fail-safe system but would still be reliant on the existing train control infrastructure. Therefore, it would still be sensitive to human errors involving miscommunication between railway employees (rail traffic controller (RTC), onboard employees, and engineering crews) and unprotected overlap of authority-type incidents would not be fully preventable. As described previously, it was assumed at Level 4 that the ETC system would incorporate and enforce all on-board operating authorities as well as confirm and validate the release of all operating authorities. However, human errors and unprotected overlap of authority-type incidents will still not be fully preventable as engineering equipment and crews are not ETC protected at any Level. Miscommunication between the RTC and engineering crews as well as a foreman and a sub-foreman on the track can lead to overlapping authorities with an oncoming train even if the train's authorities are fully controlled by the ETC system.

4.1.9 Movement Exceeds Limits of Authority (MELA)

For MELA-type incidents in RODS, it was assumed that the ETC system could not account for track condition changes occurring suddenly in front on the train (dropped signals) as, similar to the human crew, the system would not react in time to stop the train before passing the signal. In addition, while train length information could be included in the ETC system at Levels 3 and 4, it was assumed that the system would not be able to protect against slack running out after the release of the train breaks causing the rear end of the train to exceed its authority limits. When assessing incidents involving trains entering a foreman's authority limits, the information in RODS was not always sufficiently accurate to distinguish whether the work zone was an established work zone (Rule 42, etc.) or a temporary TOP. All four Levels of the ETC hierarchy

defined by CaRRL were assumed to be capable of providing protection for all types of foreman's authorities so this differentiation was not a limiting factor in this analysis.

These pre-defined assumptions based on the ETC system architecture and functionality required to address specific issues encountered when assessing the RODS database are critical to the final ETC assessment results. Changes to the ETC system functionality will lead to a different set of associated assumptions and different assessment results.

4.2 ETC Assessment

The assessment of the RODS database was performed by incident type (Table 1-5). For incident types for which the addition of an ETC system was expected to have an impact on occurrence prevention (MELA, main-track train collisions, unprotected overlap of authorities, etc.), records in RODS were assessed individually. In categories containing occurrences that were primarily expected to not be preventable by ETC (fire, employee, crossing, etc.), thorough spot checks and keyword searches were preformed to validate that assumption and identify specific incidents for closer examination.

When an occurrence was deemed to be ETC preventable, it was assigned the minimum ETC Level required to prevent the occurrence along with the corresponding ETC functionality. To illustrate the assessment process, consider the following modified MELA incident description (which has been slightly modified to protect the privacy of the operator);

> *Approaching a meet, Train A reported to the RTC that they had passed signal Z displaying stop indication by ½ car lengths. The train then backed up without authority. No other movements in the block reported.*

This incident was determined to have been preventable if a Level 1 ETC system had been installed. The ETC system would have alerted the crew to begin stopping the train earlier so as to not pass the signal indicating stop. This particular occurrence also contains a second MELA incident: subsequent to passing the signal at stop, the crew then reversed the train without permission. Such a move would have only been preventable starting at ETC Level 3, but would not have been required had the crew not originally passed the signal at stop. As passing the stop

signal was the inciting MELA incident, the whole occurrence was therefore assessed to be preventable at ETC Level 1.

A second illustrative example describes an ETC preventable non-main-track train collision occurrence that was identified after a thorough keyword search. Non-main-track train collisions were not expected to yield many ETC-preventable incidents due to the assumption that ETC would not be installed/enabled for trains not on main track (Table 1-7). Similar to the first example, the incident description has been modified to protect the privacy of the operator.

> *While proceeding down the main track, the crew on Train B noticing a misaligned switch, immediately placed the train into emergency, but were unable to stop in time and diverted into an adjacent yard. The train collided with the lead box car from a cut of cars stationary on the yard track. As a result of the collision, 2 locomotives and 7 cars from Train B derailed. The impact pushed the stationary cut of cars 600 feet down the yard track but all equipment remained upright.*

This particular incident was determined to have been preventable starting at ETC Level 3. Beginning at ETC Level 3, all mainline switches would have been monitored and their aspect information would have been available to the train crew. The train crew would have then been able to stop the train prior to reaching the switch point and the collision would have been avoided.

Assessing incidents that were ultimately determined not to be ETC-preventable revealed multiple reasons why the ETC system would often have had no effect. For example, consider a derailment caused by a broken rail while a yard assignment was performing a switching move on yard track. Individually, the broken rail, the yard assignment, performing a switching move, and the incident occurring on yard track would each have qualified the incident as being non-ETC preventable. A hierarchical approach was used to standardize the single reason assigned to each non-preventable occurrence. The primary rationale for why a particular occurrence would not be ETC-preventable was that it did not occur on the main track. This was then followed by the incident involving a yard assignment or being a switching move, in decreasing order of priority. If the non-ETC-preventable incident occurred on main track, did not involve a yard assignment, and

was not a switching move, the most relevant specific rationale related to the assumptions made in Tables 1-7 and 1-8 was assigned to the incident.

5 Results of the ETC Assessment

5.1 The Full Dataset

As introduced in the description of the RODS database, the January 2, 2000 through May 1, 2017 RODS database contained 26,685 individual occurrences and each were assessed from an ETC preventability perspective as part of this study. However, the information in RODS related to occurrences prior to 2007 often lacked sufficient descriptive details to make a reliable ETC preventability assessment. Furthermore, the additional assigned factors information used to supplement the RODS database (Table 1-6) only extended back to 2006. In light of these two issues, only the assessment results for the ten-year period between 2007 and 2016 are presented here. This 10-year period included a total of 14,036 individual occurrences (Table 1-5). The ETC assessment results can also not be easily parsed between passenger and freight operations due to the lack of immediate identifier in the RODS occurrence descriptions.

It is important to note that this assessment is based on the version of the RODS database extracted by the TSB and provided to CaRRL in spring 2017. Occurrences that had yet to be included in RODS at that point would not have been included in the extracted database and will not contribute to the results of this analysis.

While only the 2007-2016 ETC assessment results are presented here, every RODS occurrence extending back to 2000 was assessed from an ETC-preventability perspective. Even when considering the full 2000-2016 RODS dataset, the ETC-preventability results do not vary significantly from what is presented for the 2007-2016 RODS dataset.

Occurrences included in RODS are classified into one of 22 different incident types, and the ETC assessment concluded that 13 of these categories contained no ETC-preventable occurrences. These 13 categories, the associated number of occurrences, and their proportion with respect to the full RODS dataset are tabulated in Table 1-9. In total, occurrences associated with these 13 incident types account for 10,264 (73.1%) of all 2007-2016 occurrences.

Table 1-9. Summary of RODS incident categories found to contain no ETC-preventable occurrences.

	# of Associated Occurrences	Proportion of 2007-2016 Occurrences (14,036)
Crossing	1912	13.5%
Fire	241	1.7%
Historical	0	0.0%
Crew Member Incapacitated	16	0.1%
Track Unit Derailments	129	0.9%
Trespasser	711	5.1%
Employee	101	0.7%
Non-Main-Track Train Derailment	6091	43.4%
Rolling Stock Damage without Derailment or Collision	149	1.1%
Dangerous Goods Leaker	699	5.0%
Runaway Rolling Stock	123	0.9%
Explosion	1	0.0%
Rolling Stock Collision with Abandoned Vehicle	94	0.7%

The nine remaining RODS categories contain 3,772 occurrences. Similar to Table 1-9, the number of occurrences and proportions represented by the nine RODS categories containing at least one ETC-preventable incident are summarized in Table 1-10.

Table 1-10. Summary of RODS incident categories found to contain at least one ETC preventable occurrence.

	# of Associated Occurrences	Proportion of 2007-2016 Occurrences (14,036)
Track Unit Collisions	235	1.7%
Movement Exceeds Limits of Authority (MELA)	1168	8.3%
Main-Track Switch in Abnormal Position	82	0.6%
Main-Track Train Derailments	964	6.9%
Main-Track Train Collisions	54	0.4%
Non-Main-Track Train Collisions	980	7.0%
Rolling Stock Collision with Object	210	1.5%
Unprotected Overlap of Authorities	58	0.4%
Signal Less Restrictive than Required	21	0.1%

Table 1-11 presents the number of occurrences preventable at each ETC Level for the nine RODS categories found to contain at least one ETC-preventable occurrence (Table 1-10). Notably, the number of preventable occurrences at ETC Level 3 also includes all of those preventable at Level 1. A Level 3 ETC system builds upon the Level 1 system with increased

functionality but maintains the Level 1 functionality. Similarly, situations prevented by the Level 4 ETC system include those preventable at Levels 1 and 3.

Table 1-11. Summary of ETC-preventable occurrences by occurrence type and ETC Level.

	# of ETC-Preventable Occurrences			# of Non-ETC-Preventable Occurrences
	Level 1	Level 3	Level 4	
Track Unit Collisions	7	8	8	227
MELA	463	527	682	486
Main-Track Switch in Abnormal Position	4	66	66	16
Main-Track Train Derailments	11	22	23	941
Main-Track Train Collisions	11	11	17	37
Non-Main-Track Train Collision	-	3	3	977
Rolling Stock Collision with Object	-	1	1	209
Unprotected Overlap of Authorities	2	2	17	41
Signal Less Restrictive than Required	-	2	20	1

A Level 2 ETC system was not included in Table 1-11 because it is an intermediate step between the ETC Level 1 and 3 systems. Recall that a Level 2 system would be very similar to the proposed Level 1 system but with the addition of selected instrumented switches and incremental, non-vital enforcement of authority functionality. Without prior knowledge of exactly which mainline switch points would be instrumented, the number of additional occurrences that would have been prevented at Level 2 relative to the Level 1 system could not be accurately determined (but would be between zero and the number prevented at ETC Level 3). As such, the decision was made to neglect the intermediary ETC Level 2 and assess whether an occurrence would be preventable at ETC Levels 1, 3, or 4, recognizing that the proportion preventable at Level 2 would be somewhere between the values for Levels 1 and 3.

Based on the ETC assessment results presented in Table 1-11, the proportion of 2007-2016 RODS occurrences that would have been preventable had a particular Level of ETC system been installed can be quantified:

- Level 1 ETC system → 3.55% of all 2007-2016 RODS occurrences (498 of 14,036)
- Level 3 ETC system → 4.58% of all 2007-2016 RODS occurrences (642 of 14,036)
- Level 4 ETC system → 5.96% of all 2007-2016 RODS occurrences (837 of 14,036)
- Not ETC preventable → 94.04% of all 2007-2016 RODs occurrences (13,199 of 14,036)

These results highlight that only a small percentage of occurrences from the RODS database (3.5-6%) would have been preventable with some type of proposed ETC system. Furthermore, Table 1-11 clearly shows that the bulk of ETC-preventable occurrences are MELA incidents (e.g., 82.1% of all ETC Level 3 preventable occurrences). Note this assessment assumes:

- 100% crew response to all warnings from the ETC system;
- ETC system engaged and operating 100% of the time; and
- ETC system experiences no wrong side operational failures.

CaRRL recognizes that 100% operability and 100% compliance is not achievable in real-world operations. However, it was determined that the purpose of this analysis would be better served by not introducing any additional variability parameters.

Based on the assessment results, the key functionality at the proposed ETC Levels that provide the most benefit in terms of occurrence prevention can be analyzed. Figure 1-6 presents the breakdown by key ETC system functionality for the ETC Level 1 preventable occurrences (498 in total). The main occurrence-triggering action that would be addressed by a Level 1 ETC system is clearly the passing of signals indicating stop. These type of occurrences account for more than 50% of all occurrences preventable with a Level 1 ETC system. This is followed by the ETC system preventing unauthorized entry into foreman's authority limits and authorized work zones as well as preventing trains from exceeding their authority limits.

Figure 1-7 presents a similar breakdown to that presented in Figure 1-6 but for occurrences preventable at ETC Level 3 (642 in total). As the Level 3 ETC system builds on the functionality of the Level 1 system, the ability to stop trains before passing a signal at stop remains a key component of the system (accounting for approximately 40% of ETC Level 3 preventable occurrences). The major increase in ETC system complexity between Levels 1 and 3 is the monitoring of all mainline switch positions. As presented in Figure 1-7, the monitoring of mainline switch positions and the ETC system issuing a warning or taking positive enforcement when the train approaches a misaligned switch accounts for the second largest proportion of Level 3 preventable occurrences (approximately 15%).

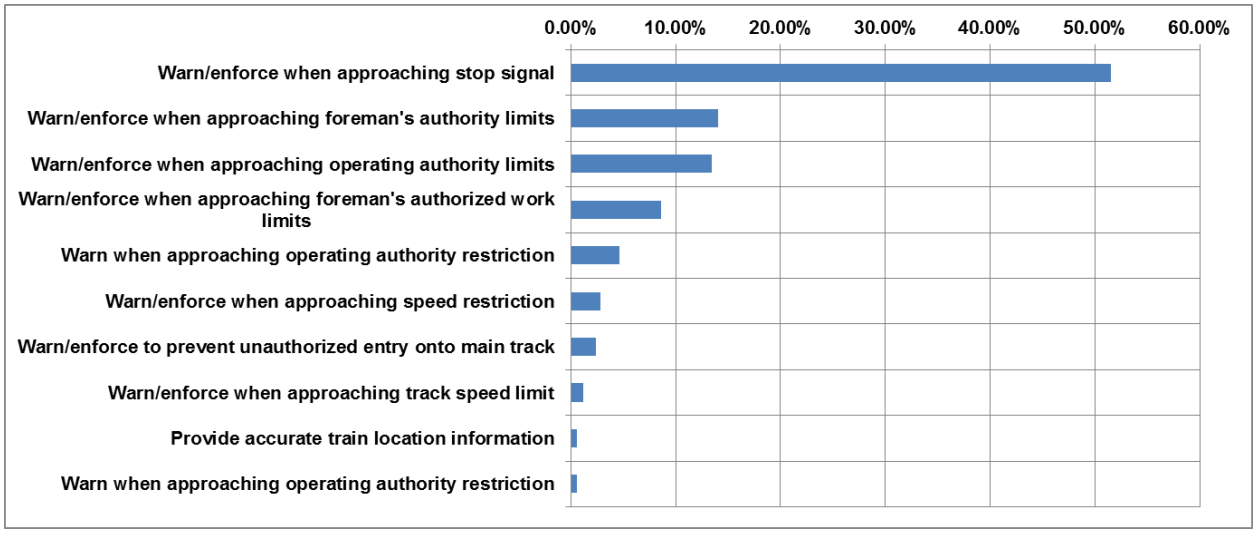

Figure 1-6. Breakdown in the key functionality of a Level 1 ETC system in terms of the number of preventable occurrences (498 in total).

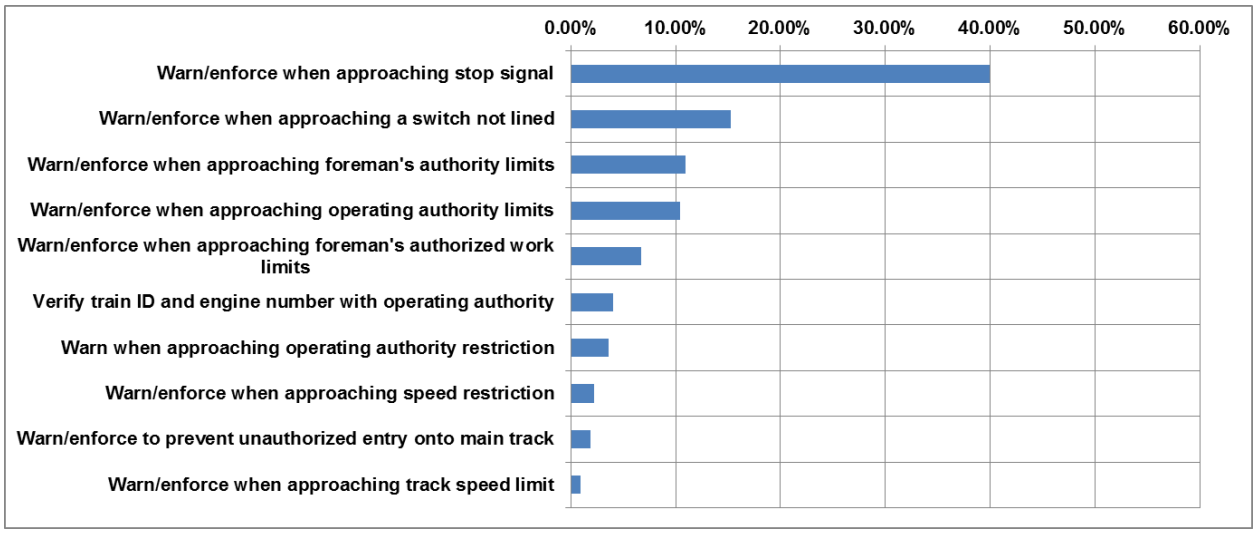

Figure 1-7. Breakdown in the key functionality of a Level 3 ETC system in terms of the number of preventable occurrences (642 in total).

Finally, Figure 1-8 presents the same breakdown for the 837 occurrences determined to have been preventable with a Level 4 ETC system. The system's ability to prevent trains from passing signals indicating stop and the monitoring of mainline switches remain key components of the Level 4 ETC system (at approximately 30 and 12%, respectively). Specific Level 4 functionality is also well represented in Figure 1-8, such as the system incorporating and controlling all

operating authorities, providing positive rear end train protection, and eliminating all wayside signals.

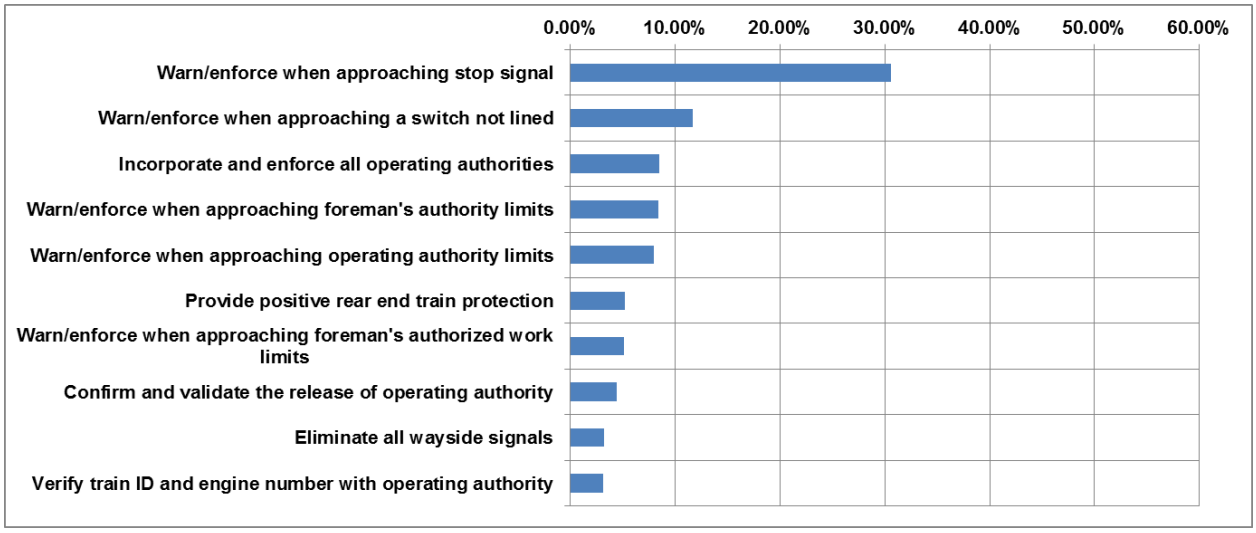

Figure 1-8. Breakdown in the key functionality of a Level 4 ETC system in terms of the number of preventable occurrences (837 in total).

In addition to investigating what functionalities in the proposed ETC system provide the most benefit in terms of the number of preventable RODS occurrences, it is also possible to analyze why the remaining occurrences are not ETC-preventable. In total, 13,199 occurrences were found to be not preventable at any ETC Level. Figure 1-9 presents the ten most common rationales for why these occurrences were not ETC-preventable.

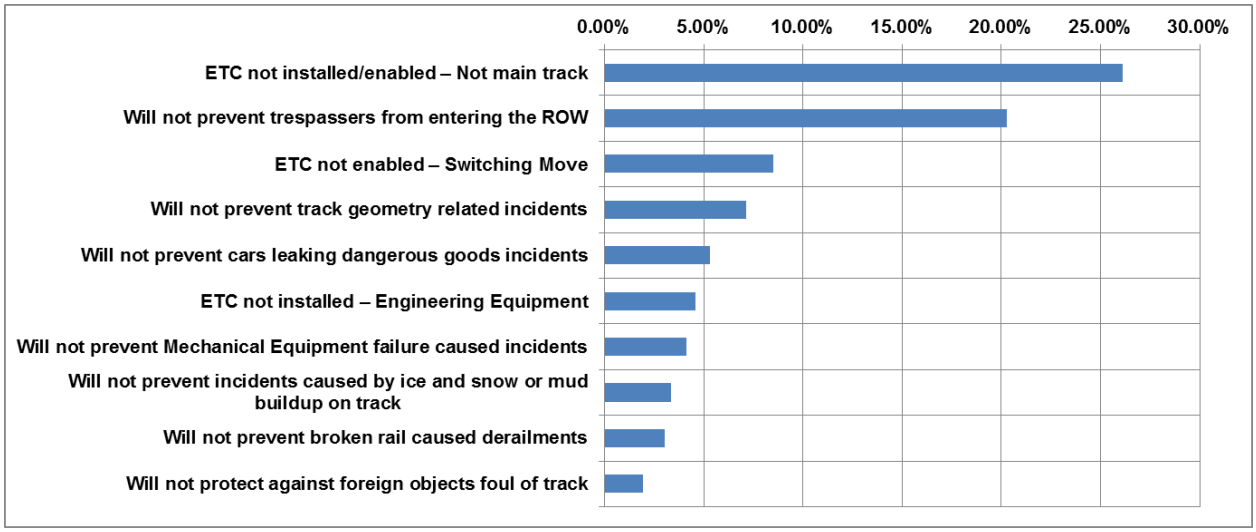

Figure 1-9. Ten most common rationales for why specific occurrences were not preventable with any Level of ETC (13,199 in total).

The two main reasons why a large proportion of the RODS occurrences were not ETC-preventable were that they occurred off mainline track or involved trespassers. Critical assumptions made prior to the assessment were that an ETC system would not be installed or enabled on non-main track and that the system would not be able to detect trespassers entering the railway ROW. A significant proportion of RODS occurrences (8.5%) also occurred while performing a switching move (during which the ETC system was assumed to be disabled).

Context with respect to the non-ETC-preventable percentages presented in Figure 1-9 and the ETC-preventable percentages presented in Figures 1-6 to 1-8 is important. Recall the Level 4 ETC system (Figure 1-8) would have prevented the greatest number of RODS occurrences (837 in total; Table 1-11). While track geometry issues were only the fourth most common reason why RODS occurrences were not ETC preventable (Figure 1-9), they combine to account for 944 individual occurrences. Therefore, the number of non-ETC-preventable RODS occurrences related to track geometry issues is actually greater than the total number of occurrences that would have been preventable with the most complex ETC system considered.

5.2 Annual, Seasonal, and Daily Breakdown of the Full RODS Assessment

5.2.1 Annual RODS Assessment Breakdown

The size of the 2007-2016 RODS database (14,036 individual occurrences) also allows for more specialized investigations to be performed. Based on the ETC assessment, annual, seasonal, and daily trends in ETC preventability were also assessed. The annual breakdown of the RODS occurrences by year is presented in Figure 1-10.

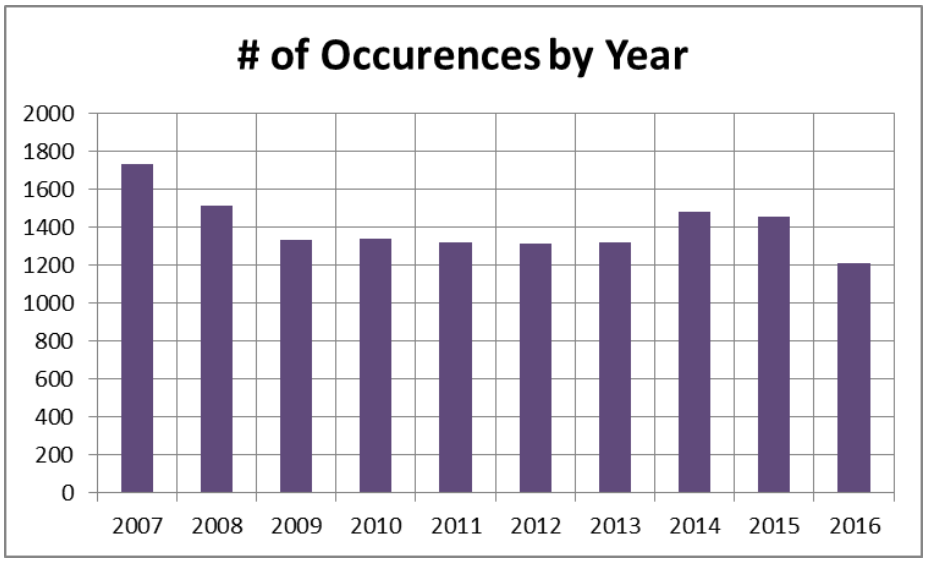

Figure 1-10. Number of occurrences contained in RODS by year (2007-2016).

The number of occurrences in RODS by year exhibits a noticeable decrease from 2007 through 2009 before reaching a relatively consistent level (of approximately 1,300) for the period 2009-2013. A slight increase in the number of annual occurrences then occurs in 2014 and 2015 before dropping in 2016 (the year with the lowest number of reportable incidents). Table 1-12 summarizes the annual number of occurrences in each of the nine categories containing at least one ETC-preventable occurrence for the period 2007-2016, as originally presented in Table 1-5.

Table 1-12. Summary of annual occurrence numbers for the nine RODS incident categories found to contain at least one ETC-preventable occurrence as well as annual total for the period 2007-2016.

	Year									
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Track Unit Collisions	30	22	30	23	23	17	23	21	32	14
MELA	106	111	108	101	119	121	98	129	143	132
Main-Track Switch in Abnormal Position	8	15	6	5	10	6	7	7	12	6
Main-Track Train Derailments	164	132	68	89	105	71	90	105	78	62
Main-Track Train Collisions	10	7	5	4	3	6	4	9	4	2
Non-Main-Track Train Collisions	111	97	99	95	91	106	95	114	96	74
Rolling Stock Collision with Object	4	6	15	3	18	19	32	31	31	51
Unprotected Overlap of Authorities	8	7	7	5	7	5	4	5	6	4
Signal Less Restrictive than Required	0	3	1	4	3	1	1	2	5	1
Total	*400*	*400*	*339*	*329*	*379*	*352*	*354*	*423*	*407*	*346*

The number of annual track unit collision, main-track switch in abnormal position, and signal less restrictive than required occurrences are relatively consistent for the ten-year period between 2007 and 2016, while the annual number of main-track train derailments, train collisions (both main-track and non-main-track), and unprotected overlap of authority occurrences decreases. In contrast, slight increases in the annual numbers of occurrences between 2007 and 2016 are observed in both the MELA and rolling stock collision with object categories. Overall, however, the annual number of occurrences in the nine categories containing at least one ETC-preventable occurrence is fairly consistent. The proportions of all annual occurrences determined to be ETC-preventable at Levels 1, 3, and 4 are presented in Figure 1-11.

Small fluctuations in the proportion of annual occurrences determined to be ETC-preventable are evident but, overall, the preventability levels are similar to the combined 2007-2016 results (3.55% at ETC Level 1, 4.58% at ETC Level 3, and 5.96% at ETC Level 4).

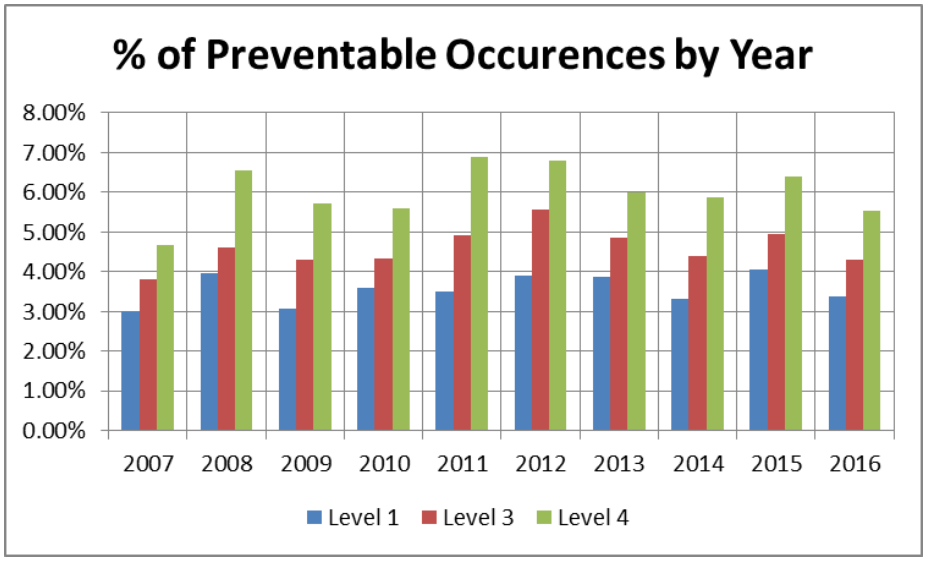

Figure 1-11. Annual proportions of ETC-preventable occurrences for the period 2007-2016.

5.2.2 Seasonal RODS Assessment Breakdown

To determine any seasonal impact on ETC preventability, each year was subdivided into four seasons: winter (Dec-Feb), spring (Mar-May), summer (Jun-Aug), and fall (Sep-Nov). Incidents occurring in different years were considered together as long as they took place in the same season. The results reveal no seasonal change in either the total number of occurrences (Figure 1-12) or ETC preventability (Figure 1-13).

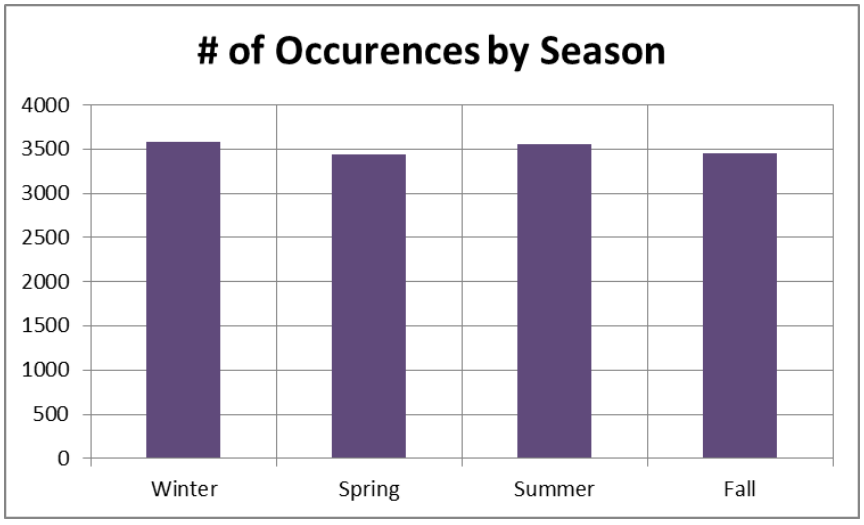

Figure 1-12. Number of occurrences contained in RODS by season.

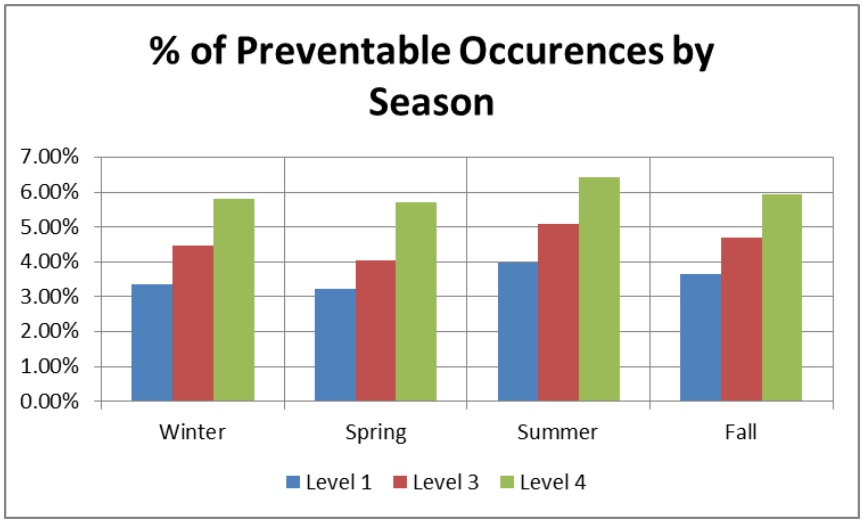

Figure 1-13. Proportion of ETC-preventable occurrences at each ETC Level by season.

The number of occurrences per season does not change throughout the year, remaining very consistent at close to 3,500. The proportions of Level 1, 2, and 4 ETC-preventable occurrences also do not fluctuate significantly between the winter, spring, and fall. The proportions are slightly greater in the summer, apparently related to the proportion of occurrences preventable with an ETC Level 1 system. A deeper investigation into the assessment results revealed the number of RODS occurrences related to a train passing a signal indicating stop also peaks in the summer, likely raising the summer ETC Level 1 preventability proportion. A greater number of passed signals at stop may be related to the amount of freight operations in the summer. The summer interval difference between Level 1 and Level 3 as well as Level 3 and Level 4 is similar to the results in the other seasons.

5.2.3 Daily RODS Assessment Breakdown

Finally, to investigate daily trends in ETC preventability, each day was separated into four local six-hour intervals (0000-0600, 0600-1200, 1200-1800, 1800-2400), with no differentiation made for time zone, year, or season. The total numbers of RODS occurrences falling within each six-hour window are presented in Figure 1-14, while the ETC preventability results are presented in Figure 1-15.

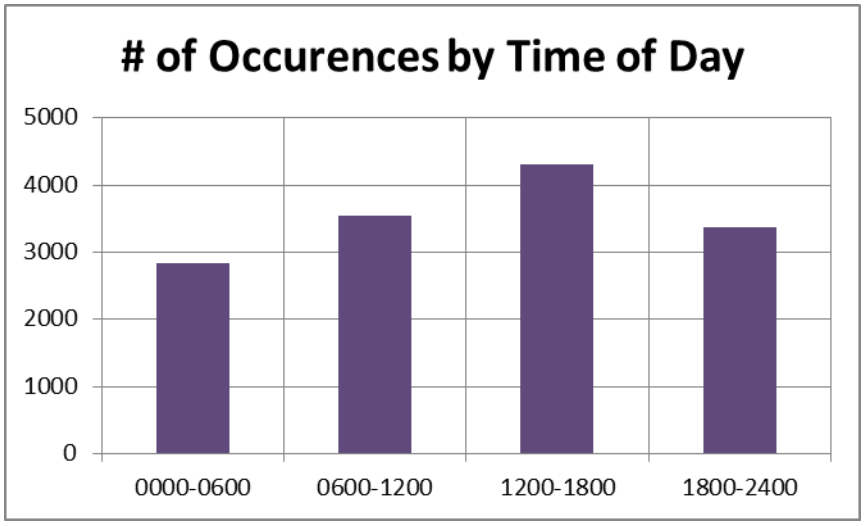

Figure 1-14. Number of occurrences contained in RODS by time of day.

The distribution of RODS occurrences throughout a 24-hour period (Figure 1-14) reveals that more incidents occur in the morning and afternoon than in the evening. This is likely related to increased railway (trains, engineering crews) as well as public (influential in crossing and trespasser incidents) activity during the day as opposed to through the night.

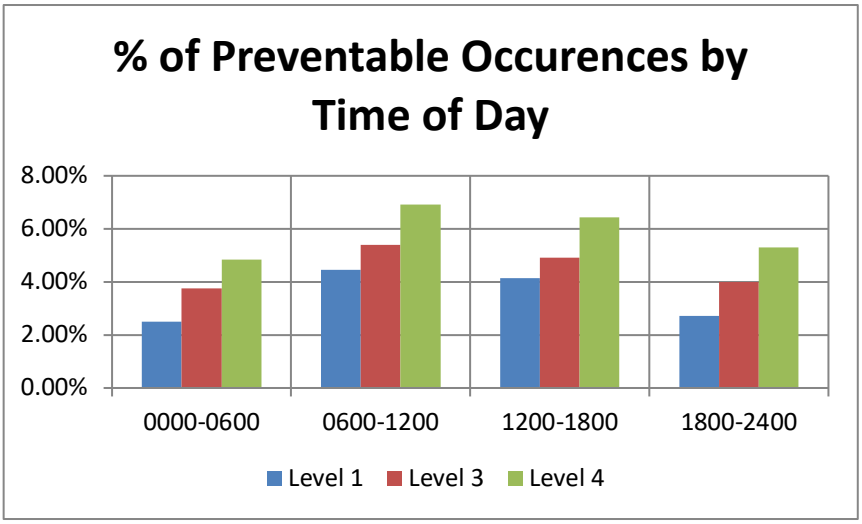

Figure 1-15. Proportion of ETC-preventable occurrences at each ETC Level by time of day.

ETC preventability also varies through the day with the highest proportions for each ETC Level observed between 0600 and 1800 local time with the 0600-1200 proportions being slightly higher. As observed for the seasonal data, the interval difference between ETC levels remains relatively constant throughout the day, indicating the change in ETC preventability is dominated

by occurrences preventable at ETC Level 1. Also similar to the seasonal results, the daily preventability pattern closely matches the distribution of occurrences in which a train has passed a signal indicating stop. More instances of trains passing signals indicating stop are observed in the 0600-1200 period followed by the 1200-1800 period, with the lowest numbers observed in the 1800-2400 and 0000-0600 periods.

5.3 Movement Exceeds Limits of Authority (MELA)

As mentioned in the preceding section, the 2007-2016 ETC preventability results are strongly influenced by the MELA incidents as they account for approximately 80% of all preventable occurrences (Table 1-11). The prevalence of MELA-related effects is also observed in the seasonal and daily breakdowns (Figures 1-13 and 1-15), for which differences in ETC preventability are predominately driven by the number of instances where trains pass a signal indicating stop. This section provides a detailed breakdown of the MELA occurrences in terms of the main types of occurrences that comprise the MELA category as well as the number preventable at each ETC Level. The breakdown of preventable MELA occurrences is presented in Table 1-13 while the breakdown of non-preventable occurrences is presented in Table 1-14. Within the snapshot of the RODS dataset provided to CaRRL by the TSB, there are 1168 incidents flagged as MELA-type occurrences (2007-2016); 463 of which would have been preventable with an ETC Level 1 functionality, 527 with ETC Level 3, and 682 with ETC Level 4.

Table 1-13. Breakdown of preventable MELA type occurrences by associated functionality and ETC Level. The percentage of all MELA-type occurrences represented by each category is provided in parentheses.

ETC Level	Associated ETC Functionality	Number of Preventable Occurrences (% of all MELA)
Level 1	Warn when approaching stop signal	250 (21.40%)
	Warn when approaching operating authority limits	66 (5.65%)
	Warn when approaching foreman's authorized work limits	42 (3.60%)
	Warn when approaching foreman's authority limits	62 (5.31%)
	Warn when required to protect defective crossing	1 (0.09%)
	Warn when approaching speed restriction	9 (0.77%)
	Warn to prevent unauthorized entry onto main track	11 (0.94%)
	Warn regarding After Arrival Authority requirements	4 (0.34%)
	Warn to prevent unauthorized reverse movement	4 (0.34%)
	Provide accurate train location information	3 (0.26%)
	Warn when approaching operating authority restriction	19 (1.63%)
Level 3	Warn when approaching a switch not lined	28 (2.40%)
	Verify train ID and engine number with operating authority	26 (2.23%)
	Monitor all mainline switch positions	1 (0.09%)
Level 4	Provide positive rear-end train protection	38 (3.25%)
	Confirm and validate the release of operating authority	37 (3.17%)
	Incorporate and enforce all operating authorities	57 (4.88%)
	Eliminate all wayside signals	7 (0.60%)
	Enforce foreman's instructions to train	16 (1.37%)

Table 1-14. Breakdown of non-preventable MELA type occurrences. The percentage of all MELA-type occurrences represented by each category is provided in parentheses.

Rationale for the MELA Occurrence being Non-ETC Preventable	Number of Occurrences (% of all MELA)
ETC not installed – Engineering equipment	248 (21.23%)
ETC not installed – Yard assignments	66 (5.65%)
ETC not installed – rolling stock without locomotives	11 (0.94%)
ETC not installed – non-main track	5 (0.43%)
ETC not enabled – work train operations	7 (0.60%)
ETC not enabled – switching move	73 (6.25%)
ETC not enabled – not main track	2 (0.17%)
ETC will not protect rear of train from slack running out	26 (2.23%)
Incorrect authority issued to train (RTC system error)	1 (0.09%)
ETC cannot protect track condition change in front of train	13 (1.11%)
Human error – employee not clear of track	9 (0.77%)
Human error – incorrect instructions to/from foreman	3 (0.26%)
Human error – misplaced work flag	1 (0.09%)
Human error – RTC error in issuing, changing or removing track protection	21 (1.80%)

Tables 1-13 clearly demonstrates that a major component of ETC preventable MELA occurrences are related to train passing signals at stop (Figures 1.6-1.8), while the enforcement

of foreman's authority limits as well as train operating authority limits are also critical components of the ETC functionality at Level 1. At ETC Level 3, the monitoring switch positions and verification of train identifications and engine numbers provide the bulk of the additional ETC preventability. Finally, at ETC Level 4 there are a significant number of MELA occurrences that could have been prevented through accurate rear-end train protection (related to trains backing through a signal at stop or releasing track while the rear-end of a train still occupies the main track after pulling into a siding), incorporating all operating authorities within the ETC system itself and allowing the ETC system to confirm and validate the release of operating authorities.

The main rationales for why the proposed ETC functionality would not have been able to address the remaining 486 MELA occurrences are presented in Table 1-14. The majority of these occurrences involve equipment where the ETC system would not be expected to be installed (engineering equipment, yard assignments) or take place in situations where the ETC system was assumed to not be enabled (switching moves).

5.4 Main-Track Train Collisions and Derailments

As part of the data assessment, a separate ETC preventability analysis was performed on the select RODS occurrences corresponding to main-track train collisions and main-track train derailments. Incidents in these categories include almost all of the high visibility railway accidents and therefore CaRRL determined that a separate data analysis might provide useful insights on ETC safety benefits.

Table 1-15 summarizes the proportions as well as total numbers of main-track train collisions and derailments determined to be preventable at each ETC Level, both individually as well as for a combined accident (main-track train derailments and collisions) dataset.

Table 1-15. ETC preventability of main-track train collisions and derailments. The number of occurrences associated with each percentage is provided in parentheses.

	% of ETC-Preventable Occurrences			% of Non-ETC-Preventable Occurrences
	Level 1	Level 3	Level 4	
Main-Track Train Collisions	20.37% (11)	20.37% (11)	31.48% (17)	68.52% (37)
Main-Track Train Derailments	1.14% (11)	2.28% (22)	2.39% (23)	97.61% (941)
Combined Accident Dataset	2.16% (22)	3.24% (33)	3.93% (40)	96.07% (978)

Immediately evident is that a much greater proportion (on a percentage basis) of main-track train collisions would have been preventable compared to main-track train derailments at each ETC Level. Again, this assessment assumes 100% crew responsiveness and the ETC system operating as envisioned. However, Tables 1-10, 1-11, and 1-15 show that considerably more main-track train derailments (964 in total) than main-track train collisions (54) occurred in the ten-year period between 2007 and 2016. For this reason, the combined accident dataset ETC preventability proportions more closely match those for the main-track train derailments as opposed to main-track train collisions.

Table 1-15 also clearly shows the changes in preventability between ETC Levels are different for main-track train collisions and derailments. For instance, there is no change in the proportion of main-track collisions that would be prevented with a Level 1 ETC system vs. a Level 3 ETC system. However, increasing ETC system complexity to ETC Level 3 doubles the number of main-track train derailments that would be prevented at ETC Level 1. For main-track train collisions, the major increase in accident preventability occurs between Levels 3 and 4. Figure 1-16 presents the breakdown in beneficial ETC functionality for both accident types at ETC Level 4.

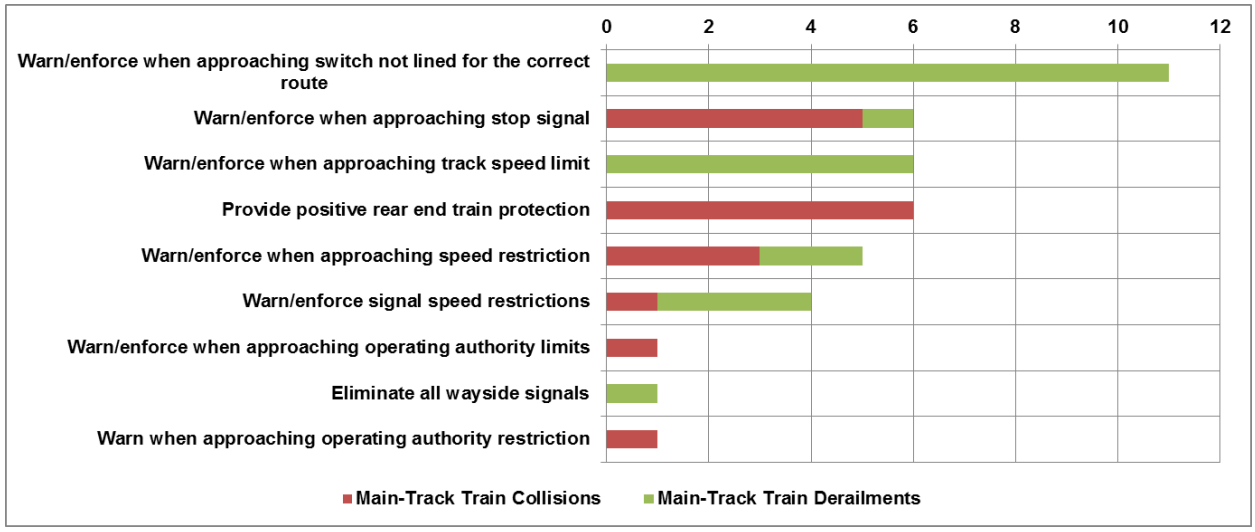

Figure 1-16. Breakdown in the key functionality of a Level 4 ETC system in terms of the number main-track train accidents it would prevent (40 in total). Red and green bars represent the main-track train collision and derailment contributions, respectively.

While Figure 1-16 presents the results for a Level 4 ETC system, the occurrence preventability gained with a Level 1 or Level 3 ETC system can also be assessed. Figure 1-16 clearly shows the positive impact of mainline switch monitoring beginning at ETC Level 3. Based on the 2007-2016 main-track accident RODS dataset, the capability to monitor mainline switch positions is solely associated with preventing main-track train derailments (green portions of each bar) and is why the number of preventable main-track train derailments doubles between ETC Levels 1 and 3 (Table 1-15). However, as demonstrated previously when discussing how individual RODS occurrences were assessed, main-track switch monitoring would have also prevented at least one non-main-track train collision.

The importance of controlling train speeds (track, restricted, or signal speeds) with a Level 1 ETC system to prevent main-track train derailments is also clearly demonstrated in Figure 1-16. For main-track train collisions, the major benefits are derived from preventing trains from passing stop signals and warnings regarding approaching speed restrictions (both at ETC Level 1) as well as providing positive rear end train protection (at ETC Level 4). Figure 1-16 shows that for the period between 2006 and 2017:

At ETC Level 1

- Enforcement of stop signals would have prevented five main-track train collisions and one main-track train derailment;
- Enforcement of track speed and speed restrictions would have prevented four main-track train collisions and 11 main-track train derailments;

At ETC Level 3

- Switch monitoring would not have prevented a main-track train collision but would have prevented 11 main-track train derailments;

At ETC Level 4

- Positive rear end train protection would have prevented six main-track train collisions but no main-track train derailments.

Similar to Figure 1-9, Figure 1-17 highlights the most common reasons why main-track train accidents (collisions and derailments) are not ETC-preventable.

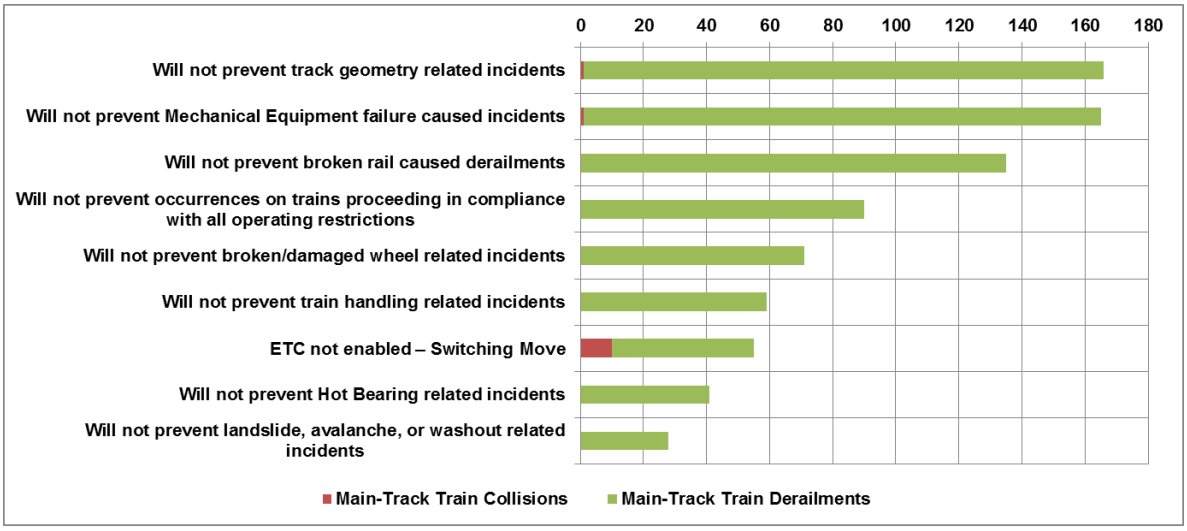

Figure 1-17. Breakdown of the most common reasons why main-track train accidents are not ETC-preventable. Red and green bars represent the main-track train collision and derailment contributions, respectively.

Due to the large number of main-track train derailments (964) compared to main-track train collisions (54), Figure 1-17 is not surprisingly dominated by the main-track train derailment

components (in green). The only factor significantly influenced by main-track train collisions is related to collisions occurring during switching moves when the ETC system would not have been enabled. The remaining factors are related to either mechanical (broken rails/wheels), engineering (track geometry), or train handling issues that would not have been addressed by the proposed ETC system.

Comparing the proportions of preventable main-track train accidents (Table 1-15) with the proportions for the full RODS database of incidents presented previously shows the accident percentages are significantly lower than the incident percentages at each ETC Level. Based on Table 1-11, this is not unexpected due to the large number of preventable MELA-type incidents that are not considered when analyzing only mainline accidents. The low preventability values imply that a large number of main-track train accidents are not related to issues the proposed ETC system attempts to address (overspeed derailments, train-to-train collisions, misaligned switches, and entering foreman's work limits). A comparison of Figures 1-16 and 1-17 highlights that four times as many main-track train accidents are related to either track geometry (165) or mechanical equipment failures (164) than would be preventable with a Level 4 ETC system (41).

5.5 Comparison with Previous Work

The ETC preventability assessment results described in this section can also be compared with the results of the assessment performed previously by the Train Control Working Group (WG). In their assessment of the publicly available RODS data as well as the TSB Statistical Summary of Railway Occurrences, the WG estimated that 5.6% of all railway occurrences would have been preventable with a US PTC-type train control system. The Level 3 ETC system proposed here is the most similar ETC system to the US PTC and was found to prevent 4.58% of all RODS occurrences.

The small discrepancy is likely a result of the more cursory WG analysis of the RODS database compared to the more thorough and in-depth analysis performed here. For instance, the WG concluded that all main-track train collisions would have been ETC-preventable with a PTC-type system based on the assumption that PTC is designed to prevent train-to-train collisions. However, this analysis based on the detailed RODS descriptions shows that only 20.37% of main-track train collisions would have been preventable with a Level 3 ETC system (the most

similar ETC Level to the US PTC system). The in-depth analysis highlighted that many of the factors leading to main-track train collisions (open doors on passing trains, collisions between rolling stock without locomotives, or collisions during switching moves) are, in fact, not ETC preventable.

Based on the assumptions that the available railway occurrence information required the WG to make, the small difference between their PTC preventability estimate (5.6%) and the ETC Level 3 estimate prepared here (4.58%) is noteworthy. However, the ETC preventability values determined during this detailed analysis of the RODS database (3.55% at ETC Level 1, 4.58% at ETC Level 3, and 5.96% at ETC Level 4) are more representative of the maximum prevention rates that could be expected from an ETC system with the proposed functionality.

6 Conclusions and Future Work

6.1 Conclusions

Based on recommendations made by the ETC WG in their final report to ACRS, CaRRL was provided a mandate by TC to perform an in-depth assessment of the TSB RODS database and determine the proportion of occurrences that would have been preventable with an ETC-type system.

The preliminary component of this analysis involved developing the functionality of the proposed ETC system. Recognizing the wide variability in train control systems and operating environments, CaRRL developed a four-tier hierarchical ETC functionality framework with which to assess the RODS records. ETC systems at Levels 1 through 3 represent overlays onto existing train control methodologies.

- A Level 1 system was envisioned as a locomotive-centric, crew assist and monitoring system with no wayside buildouts.
- The Level 2 system built on a Level 1 system incorporating non-vital enforcement and selected wayside (signals and switches) buildouts.
- At Level 3, the ETC system builds upon Level 2 and involves full buildouts, monitoring all wayside locations and providing vital train control enforcement. The Level 3 system would be similar to the US PTC system.
- The proposed Level 4 ETC system would involve a complete replacement of existing train control technologies with a fully vital, moving block train control system.

Table 1-16 summarizes the proposed high-level ETC system functionality for the four key parameters:

- Prevention of over speed derailments;
- Prevention of train-to-train collisions;
- Prevention of trains occupying improperly aligned switches; and
- Prevention of trains entering a foreman's work authority limits.

With the hierarchical ETC framework intended to focus on addressing the four key parameters listed above, there will be a significant number of incidents that proposed ETC functionality will not be able to address. As such, when characterizing the proportion of preventable occurrences at each ETC Level relative to all railway incidents, the expectation is that the preventability will be small. However, for the type of railway occurrences related to the four key operating objectives of ETC, it is expected that the rate of incident preventability will increase.

Table 1-16. Summary of ETC system functionality.

ETC Systems - Occurrence Prevention			**Level 1 (Non-Vital)**	**Level 2 (Non-Vital)**	**Level 3 (Vital)**	**Level 4 (Vital)**
Key Parameters	**Sub-functionality Requirements**		**Crew Assist & Monitor**	**Crew Assist & Enforce**	**US Type PTC**	**Moving Block**
Train-to-Train Collisions	Controlled absolute signals	Stop signal	Warn	Enforce	Enforce	Enforce
		Speed if signal not at stop	Warn	Enforce	Enforce	Enforce
		Stop on aspect change to stop*	Warn	Enforce	Enforce	Enforce
	Intermediate signal aspects	Stop signal	No	Partial	Enforce	Enforce
		Speed if signal not at stop	No	Partial	Enforce	Enforce
		Stop on aspect change to stop*	No	Partial	Enforce	Enforce
	Form based authorities	OCS clearance	Warn	Enforce	Enforce	Enforce
		After arrival OCS clearance	No	No	Enforce	Enforce
		Authority to enter main track	Warn	Enforce	Enforce	Enforce
		Authority to pass red signal	No	Enforce	Enforce	Enforce
Overspeed Derailments	Speed restrictions	Civil speed restrictions	Warn	Enforce	Enforce	Enforce
		Permanent speed restrictions	Warn	Enforce	Enforce	Enforce
		Temporary speed restrictions	Partial	Enforce	Enforce	Enforce
		Signal speed restrictions	No	Partial	Enforce	Enforce
		Consist speed restrictions	Warn	Enforce	Enforce	Enforce
		Speed over switches	No	Partial	Enforce	Enforce
		Restricted speed	Warn	Enforce	Enforce	Enforce
	Protect head end only speed restriction		Warn	Enforce	Enforce	Enforce
	Protect full train speed restrictions		No	Partial	Enforce	Enforce
Misaligned Switch	Misaligned switch	Not lined correctly for the authorized route	No	Partial	Enforce	Enforce
		Not lined normal or reverse	No	Partial	Enforce	Enforce
	Stop for change in switch position on approach*		No	Partial	Enforce	Enforce
Entry into Authorized Work Limits	Stop prior to entering work limits unless foreman approval received		Warn	Enforce	Enforce	Enforce
	Authorized speed through work limits		No	Partial	Enforce	Enforce
	Digital authorization of speed and route from foreman		No	No	No	Enforce
	Stop prior to entering foreman's clearance/TOP		Warn	Enforce	Enforce	Enforce

* - Within braking distance

With the functionality of the ETC system defined, a comprehensive RODS database was requested from the TSB. CaRRL received a version of the RODS database from the TSB in spring 2017. However, as the RODS database is continuously updated, the extracted version received by CaRRL may not be fully up to date. The received database contained records of Canadian railway occurrences for the period between January 2, 2000 and May 1, 2017 (a total of 26,685 records). Due to variances in the descriptive quality of the initial incident summaries for pre-2007 records, however, CaRRL was unable to as conclusively assess their ETC preventability. As such, the decision was made to focus on the 14,036 RODS occurrences between January 1, 2007 and December 31, 2016. Within this ten-year period, RODS records related to main-track train derailments records were also supplemented with assigned factor information as determined by the TSB. In addition, the reports from 240 individual TSB investigations into specific occurrences listed in RODS were used to assess the preventability of these incidents from an ETC perspective.

To evaluate the ETC-preventability of individual occurrences, CaRRL was required to make specific initial assumptions related to the capability of ETC system, where the system would operate, and what types of rail vehicles would be ETC-equipped. Further assumptions were also required to address various repeated situations encountered during the assessment of the RODS database that were not accurately described by the initial assumptions. The assumptions made by CaRRL are fundamental to the results of this analysis, and a different set of assumptions will yield a different set of results.

Based on the ETC functionality and associated assumptions, the 22 occurrence categories comprising the RODS database were assessed on either an incident-by-incident basis or through keyword searches and spot checks. The latter methodology was used for incident categories where ETC technologies were not expected to provide any preventative benefit. The process of ETC assessment was as follows:

1. Determining if each occurrence was or was not preventable had an ETC system been in place;
2. If preventable, assigning the lowest ETC Level at which the incident would have been prevented; and

3. Identification of either the associated ETC functionality that would have prevented the occurrence or the main impediment to ETC prevention.

While only the *main* impediment to ETC preventability was assigned to non-ETC-preventable occurrences, individual occurrences were not ETC preventable for multiple potential reasons.

Based on the CaRRL assessment of the 2007-2016 RODS database, nine of the 22 occurrence categories contained at least one ETC-preventable occurrence. The proportions of 2007-2016 RODS occurrences that would have been preventable with the proposed ETC systems (Table 1-16) are as follows:

- Level 1 ETC system → 3.55% of all 2007-2016 RODS occurrences (498 of 14,036)
- Level 3 ETC system → 4.58% of all 2007-2016 RODS occurrences (642 of 14,036)
- Level 4 ETC system → 5.96% of all 2007-2016 RODS occurrences (837 of 14,036)
- Not ETC preventable → 94.04% of all 2007-2016 RODs occurrences (13,199 of 14,036)

A detailed analysis was not performed for the Level 2 system as it will depend on where the selected wayside buildouts are located. Therefore, the proportion of preventable occurrences for a Level 2 ETC system will fall between those for the Level 1 and Level 3 systems. As these numbers demonstrate, as expected only a small fraction (between 3.5 and 6%) of all RODS occurrences would have been preventable if the proposed ETC system been installed at the time.

The main functionalities of the ETC system responsible for the majority of the ETC benefit are related to preventing MELA-type incidents (preventing train movement through a stop signal, into a foreman's authority, or passing train authority limits); however, significant benefits were associated with the addition of switch monitoring at ETC Level 3 and the incorporation of all operating authorities into the ETC system at Level 4. Commonly used rationales for why the majority of RODS occurrences were determined not to be ETC-preventable include (but are not limited to):

- The incident occurred on non-main track or while performing switching moves;
- The incident involved trespassers entering the right-of-way;

- The incident involved non-ETC-equipped rail vehicles (engineering equipment, yard assignments etc.); and
- The incident was related to track geometry issues, broken rails, broken wheels, or other mechanical issues.

The large size of the RODS dataset also allowed CaRRL to break down the assessment results by year, season, and time of day. Little change was observed in the ETC-preventability results on an annual or seasonal basis but increased preventability was observed during the daylight hours (0600-1800) in the time of day breakdown. This was assumed to be related to an increase in the number of engineering personnel (resulting in more preventable MELA incidents) along the railways during the day.

ETC-preventability results were also broken down to analyze only MELA-type occurrences as well as main-track train *accidents* (collisions and derailments). These two sub-sets of incidents were analyzed individually as they represent occurrence types closely related to the key operating parameters of the ETC system where ETC is expected to have a greater affect in terms of incident preventability. Within the MELA RODS category, it was observed that the proposed ETC functionality would have prevented between 39.64 and 58.39% of the occurrences at ETC Levels 1 through 4. The majority of the preventable MELA occurrences are related to trains passing signals indicating stop, trains passing their operating authority limits and trains entering foreman's authority limits; all of which would have been preventable with an ETC system operating as envisioned at Level 1.

The breakdown in terms of main track accidents revealed that between 20.4 and 30.5% of main-track train collisions and 1.1 to 2.4% of main-track train derailments could have been prevented with an ETC system. Overall, due to the relatively small number of main-track train collisions (54) compared to main-track train derailments (964) over the ten-year period, only 2.1 to 3.9% of all main-track train accidents (derailments and collisions) were determined to have been ETC-preventable.

For both MELA and main-track accidents (collisions and derailments), the bulk of the ETC preventability can be achieved with the least complex ETC system (a system incorporating the envisioned Level 1 functionality). Furthermore, the proposed ETC functionality successfully

prevented incidents within the specific occurrence categories where it was intended to be beneficial; however, these occurrence categories comprise only a small proportion of the RODS database.

The proportion of all occurrences preventable with an ETC Level 3 system derived during this analysis (4.58%) is similar to the proportion reported in the final WG report (5.6%) based on their high-level assessment of the publicly available 2011-2015 RODS database. The WG based their assessment on the functionality of the US PTC system (similar to ETC Level 3) but were required to make much broader assumptions to perform their analysis on a more limited RODS dataset. While similar, the results of this more in-depth analysis are considered more accurate as well as more representative of the preventative impact an ETC system could have on Canadian railway occurrences.

While the proposed ETC systems would have reduced the number of reportable railway occurrences, the results do not preclude the possibility that other safety technologies would have been capable of preventing an even greater number of incidents. For example, consider that none of the 1912 crossing incidents and only a small number of the 964 main-track train derailments (between 11 and 23 depending on ETC Level) were determined to be preventable. Alternative safety technologies capable of addressing the causes of incidents that the ETC system cannot protect against may result in an overall greater number of preventable occurrences. However, the breadth of these technologies and their applicability to the Canadian railway environment was beyond the scope of this analysis.

6.2 Future Work

In addition to performing an in-depth ETC assessment of the RODS database, the mandate provided to CaRRL by TC also included requirements to:

1. Normalize the ETC preventability results by subdivision and corridor to facilitate comparison and risk ranking assessments;
2. Develop risk prioritization criteria for ETC implementation in Canada; and
3. Apply the risk prioritization criteria and perform a risk analysis for a selected rail corridors.

The results of this work are presented in Part B of this report. Input from the major Canadian railways to establish the normalization methodology, risk prioritization criteria, and define corridors within the Canadian railway network.

Part B

Corridor Normalization of ETC Preventability,
Risk-Based Analysis of the Impact of Enhanced Train Control Implementation,
and
Approaches for Corridor Prioritization

7 General

In early 2017, the Canadian Railway Research Laboratory (CaRRL) was contracted by Transport Canada (TC) to perform an in-depth study of the potential safety benefits to be gained through the implementation of enhanced train control (ETC) technologies in the Canadian railway environment. This study is a follow-up to previous work completed by the Train Control Working Group (WG) summarized in a final report submitted to the Advisory Council on Railway Safety (ACRS) in September 2016.

On the basis of the final ETC WG report, TC provided CaRRL with a mandate to further the study of ETC in Canada by:

1) clearly defining the functionality of a potential ETC system;
2) performing a detailed assessment of the RODS database to accurately identify the ETC-preventable occurrences (based on the proposed functionality);
3) developing risk prioritization criteria for ETC implementation in Canada; and, finally,
4) applying their risk prioritization criteria and perform a risk analysis for select rail corridors.

Part A of this study, presented as a draft in September 2017, focused on the first two points of the mandate by establishing the ETC functionality to be considered and assessing occurrence preventability for the 2007-2016 RODS database. The ETC preventability results derived in Part A are subject to the accuracy of the version of the RODS database extracted by the Transportation and Safety Board of Canada (TSB) and provided to CaRRL in spring 2017. This portion of the report (Part B) contains the results for the last two components of CaRRL's mandate and follows directly from Part A.

Part B begins by partitioning the 2007-2016 RODS database into separate mainline corridors to investigate regional changes in ETC preventability. The individual subdivisions associated with each corridor were provided by both Canadian National (CN) and Canadian Pacific (CP) so as to be representative of their respective mainline national networks. Following corridor definition and RODS partitioning, an attempt is made to normalize the ETC assessment results across the different corridors to facilitate comparisons. Normalization is required to account for the variable

potential of different corridors to generate a RODS occurrence based on corridor-specific factors (traffic amounts, existing train control infrastructure, etc.).

Part B then continues with a multi-method risk-based assessment of ETC preventability supported by severity indicators derived from the RODS database. Severity indicators are introduced to highlight the ability of the ETC system to address the *results* of RODS occurrences (dangerous goods car released, fatalities, etc.) while simultaneously investigating the raw number of RODS occurrences that would have been ETC preventable. To make use of the large statistical potential of the ETC-assessed 2007-2016 RODS database, a risk assessment methodology is developed and demonstrated at the network scale based on specific records within individual corridors. Risk ranking criteria to prioritize individual corridors for perspective ETC installation are also discussed. Finally, the ability of the proposed ETC system to address high consequence occurrences (occurrences exhibiting the most derailed cars, or the most leaking dangerous goods cars) is evaluated by extracting these records from the RODS database and investigating how many would have been ETC preventable.

8 Partitioning the ETC Assessment by Corridor

A more detailed analysis of the ETC assessment results required the 2007-2016 RODS occurrence database to be partitioned into individual rail corridors. To identify representative rail corridors, CaRRL approached the major Canadian railway operators (CN and CP) to define the major corridors (with an annual freight load >10 MGT) comprising their respective national networks. CaRRL proposed to define corridors in terms of the constituent subdivisions such that related occurrences could be readily identified in the ETC assessment of the RODS database.

In total, CN and CP provided CaRRL with 19 individual corridors (10 from CN and 9 from CP) comprising 78 individual subdivisions. Table 2-1 summarizes the 19 corridors and the individual subdivisions contained in each.

RODS-reportable incidents occurring within a specific corridor were identified from the ETC assessment results using a two-step approach:

1. The incident occurred along track belonging to either CN or CP as identified by the subdivision owner identification column in RODS; and
2. The incident occurred within one of the constituent subdivisions belonging to the corridor under investigation.

When breaking down the overall RODS occurrence database by corridor, no attempt was made to separate those incidents occurring on mainline track and those within yards. The railway networks for both CN and CP associate a yard with the specific subdivision to which it is attached. As a result, individual RODS reportable occurrences within that yard will be assigned to that subdivision and not readily distinguishable from occurrences along the mainline track in that subdivision. As yards represent a different operating environment compared to mainline track, they may be more strongly associated with specific types of RODS occurrences compared to mainline operations. Yard-related occurrences may then skew the number of RODS occurrences within each corridor as yards are not likely to be of uniform size or uniformly distributed throughout CN's and CP's networks (Table 2-1).

Table 2-1. Corridor definitions used to partition the RODS database.

Operator	Corridor	Constituent Subdivisions
CN	Montreal – Eastern Canada (MTL-ECDA)	Bedford, Springhill, Napadogan, Pelletier, Montmagny, Drummondville, St-Hyacinthe, Montreal
	Toronto – Montreal (TOR-MTL)	Kingston
	Southern Ontario (SOU-ON)	York, Halton, Dundas, Strathroy, Grimsby
	Northern Ontario (NOR-ON)	Bala, Ruel, Caramat, Allanwater, Redditt
	Jasper – Winnipeg (JASP-WPG)	Rivers, Watrous, Wainwright, Edson
	Fort Frances – Sprague (FTFR-SPRAG)	Fort Frances, Sprague
	Vancouver – Jasper (VANC-JASP)	Albreda, Clearwater, Ashcroft, Yale, Robson
	Prince Rupert – Jasper (PRIRUP-JASP)	Tete Jaune, Fraser, Nechako, Telkwa, Bulkley, Skeena
	Alberta Branch (AB-BRANCH)	Three Hills, Camrose
	Westend Prairie Northern (WESTEND-PNL)	Blackfoot, Vegreville
CP	Vancouver – Calgary (VANC-CGY)	Cascade, Thompson, Shuswap, Mountain, Laggan
	Golden – Medicine Hat (GLDN-MEDHAT)	Windermere, Cranbrook, Crowsnest, Taber
	Calgary – Edmonton (CGY-EDM)	Red Deer, Leduc
	Edmonton – Winnipeg (EDM-WPG)	Wetaskiwin, Hardisty, Wilkie, Sutherland, Wynyard, Bredenbury, Minnedosa
	Calgary – Winnipeg (CGY-WPG)	Brooks, Maple Creek, Swift Current, Indian Head, Broadview, Carberry
	Winnipeg – Thunder Bay (WPG-THNBAY)	Keewatin, Ignace, Kaministiquia
	Thunder Bay – Toronto (THNBAY-TOR)	Nipigon, Heron Bay, White River, Nemegos, Cartier, Parry Sound, Mactier
	Toronto – Montreal (TOR-MTL)	Belleville, Winchester
	Toronto – Detroit (TOR-DET)	Galt, Windsor

Figure 2-1 presents the number of RODS occurrences within each of the CN/CP defined corridors listed in Table 2-1 based on the identification procedure presented above. The corridors in Figure 2-1 are ordered from left to right in terms of decreasing numbers of RODS occurrences. Figure 2-1 shows a clear difference in the number of occurrences along different corridors. This variation in total number of RODS occurrences is driven, at least in part, by the

significant variances in corridor operating characteristics (total length, train counts, train miles, number and size of yards, etc.).

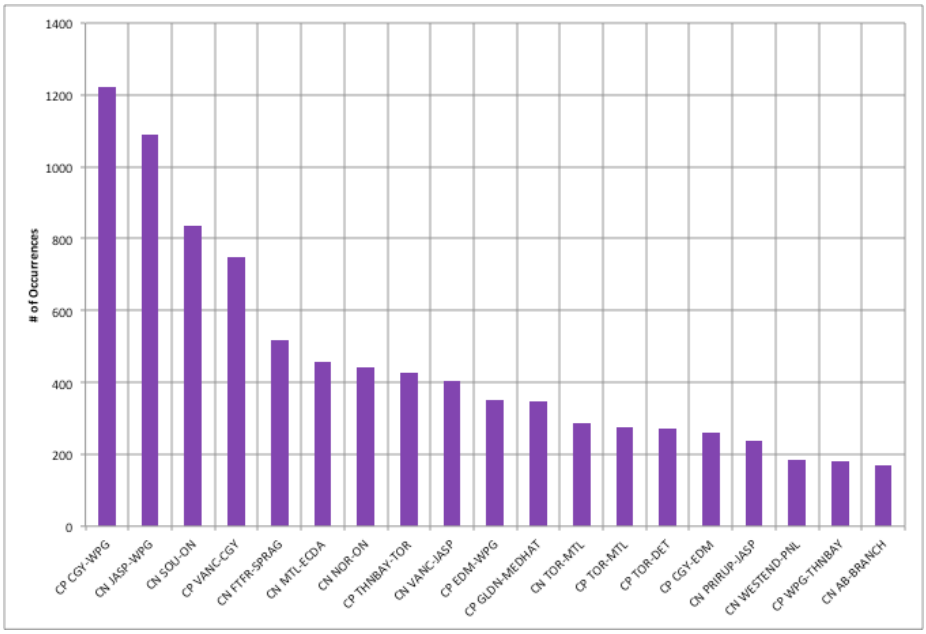

Figure 2-1. Number of RODS occurrences within each corridor defined in Table 2-1.

The corridors and subdivisions defined in Table 2-1 contain 8,701 of the 14,036 (62%) total RODS-reportable incidents that occurred between 2007 and 2016. Furthermore, Figure 2-1 represents 70% of all occurrences that took place on track owned by either CN or CP.

The ETC preventability results for each corridor and for each ETC Level (1, 3, and 4) are tabulated and presented in Table 2-2 and Figure 2-2, respectively.

Table 2-2. Summary of ETC preventability by corridor.

Corridor	# of Occurrences	# of ETC-Preventable Occurrences @			# of non-ETC-Preventable Occurrences
		Level 1	Level 3	Level 4	
CP CGY-WPG	1223	30	35	43	1180
CN JASP-WPG	1090	61	64	75	1015
CN SOU-ON	835	14	14	15	820
CP VANC-CGY	748	44	49	63	684
CN FTFR-SPRAG	516	1	3	3	512
CN MTL-ECDA	458	19	19	32	425
CN NOR-ON	441	34	37	48	392
CN THNBAY-TOR	428	15	18	32	395
CN VANC-JASP	403	19	22	26	377
CP EDM-WPG	351	11	16	21	330
CP GLDN-MEDHAT	348	21	35	48	300
CN TOR-MTL	285	23	23	31	254
CP TOR-MTL	275	5	8	13	262
CP TOR-DET	271	11	17	21	250
CP CGY-EDM	260	5	18	22	238
CN PRIRUP-JASP	236	6	7	12	224
CN WESTEND-PNL	185	8	12	17	171
CP WPG –THNBAY	180	3	3	6	174
CN AB-BRANCH	168	12	17	19	149

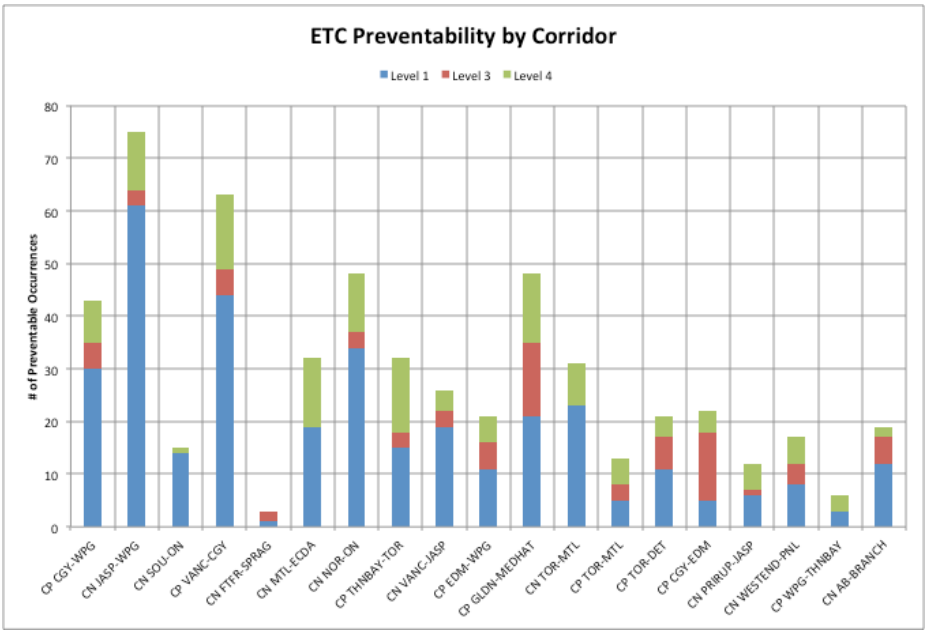

Figure 2-2. Breakdown in the number of ETC-preventable occurrences by corridor for ETC Levels 1, 3, and 4.

Table 2-2 and Figure 2-2 show the distribution of ETC preventability is only weakly related to the total number of occurrences within a particular corridor. While a general decrease in the

number of preventable occurrences is evident from left to right across Figure 2-2, corridors that contain relatively large numbers of RODS occurrences do not exhibit a correspondingly proportional amount that would have been ETC preventable (e.g., CN SOU-ON and CN FTFR-SPRAG). This variability is likely related to the number of occurrences in the non-preventable RODS incident categories (i.e., DG leakers or crossing incidents; see Part A of this report for a complete list), which can further be associated with the presence of larger yards in specific corridors. Therefore, ordering the corridors in terms of the total number of RODS occurrences may be misleading.

Table 2-2 and Figure 2-2 also demonstrate that an increase in ETC system complexity (i.e., Level 1 → 3 → 4) does not always result in the same degree of occurrence prevention. For example, the CN MTL-ECDA and CN TOR-MTL corridors would have no additional occurrences prevented had a Level 3 ETC system been deployed vs. a Level 1 system. In contrast, a significant number of occurrences would have been addressed by ETC Level 3 systems had they been installed on the CP GLDN-MEDHAT and CP CGY-EDM corridors.

The direct corridor breakdown results reflect the diverse nature of rail transportation across CN's and CP's Canadian networks. The specific features of railway operations within one corridor are not necessarily the same as those in another. Therefore, specific operational aspects of a corridor may increase the likelihood of RODS-reportable incidents. While Table 2-2 and Figure 2-2 present the overall impact of implementing ETC within each of the defined corridors, the corridors are not directly comparable without normalization.

9 Normalization of the Corridor ETC-Preventability Results

9.1 Normalization Criteria

When considering what criteria would be appropriate for data normalization, CaRRL identified a set of requirements that each criterion would have to meet:

a. Correlate with the opportunity for human error by railroad personnel;
b. Be simple, measurable, and readily available; and
c. Be comparable between operators.

The correlation between the normalization criteria and the opportunity for human error is critical because the ETC system (as defined here) is intended to decrease the number of RODS-reportable incidents occurring as a result of human error. ETC Levels 1 through 3 are overlay systems and therefore depend on the existing train control technology. ETC systems at these Levels provide no additional protection against system, equipment, or technological errors; they only ensure that railway personnel operate their trains in compliance with operating authorities provided by the existing train control system. Normalization with a criterion unrelated to the potential for human error (e.g., the number of dangerous goods cars) could distort the data and lead to erroneous interpretation of the results.

The normalization criteria should be simple and readily accessible to ensure they are broadly understandable. Normalization criteria that are too specific or difficult to comprehend may obscure the relevant results. Also critical is that the normalization criteria are measurable so as to be objective and not reliant on personal opinion.

Finally, as the corridors presented in Table 2-1 belong to both CN and CP, whatever normalization criteria are chosen must be similarly defined for the two operators so that individual corridors are comparable. While this analysis focuses on CN and CP freight operations, the normalization criteria should also be equally transferrable to other railway operators as well as passenger operations.

In light of these requirements, CaRRL proposed four criteria to normalize the ETC-preventable RODS occurrences within each corridor:

1. Train miles;
2. Train counts;
3. Train control method; and
4. Track class.

Train miles were selected as a normalization criterion as they are related to network density and track usage. Similarly, train counts were selected as they are also a proxy for train density with the additional caveat of being related to the potential for train meets. CaRRL's fundamental assumption for selecting train miles and train counts as normalization criteria was that increased train volumes and an increased number of meets will lead to greater workload demands for operating crews with a corresponding increase in the potential for human error and an ETC-preventable RODS occurrence. Both of these criteria are also simple, quantitative values that are expected to be comparable between CN and CP.

Differences in the train control methods across the various corridors will require the operating crews to be familiar with a wider range of operating rules and procedures. In addition, occupancy control system (OCS) territories will require manual copying and repeating of operating authorities. Differences in control methods will also impact the ability of the train control system to monitor train and plant operations. Similarly, centralized traffic control (CTC) track will already have active switch aspect monitoring as part of the existing train control system whereas track under OCS will not. Finally, track class acts as a proxy for train speeds as well as the general operating conditions.

9.2 Normalization Data

With the normalization criteria defined, CaRRL requested corresponding information for each subdivision represented by the 19 corridors in Table 2-1. While CP provided CaRRL with an almost fully aggregated breakdown of the normalization criteria for each subdivision, the train mile, train count, and track class data provided by CN required further processing. The train mile and train count information provided by CN was defined by train series within each subdivision, and had to be combined, while the track class information was defined by milepost within each subdivision.

The train miles and train counts belonging to each train series, except 500 series trains (locals) and yard jobs (Y-type trains), were aggregated to define total train miles and train counts within each CN subdivision. Additionally, an average track class was defined based on the relative proportion of mainline track existing at individual track classes. For example, if an 80-mile-long subdivision is comprised 20 miles of Class 3 mainline track, 50 miles of Class 4 mainline track, and 10 miles of Class 5 mainline track, the entire subdivision would be classified as Class 4 as it contains the greatest relative proportion of this class of track.

The sole edit to the CP normalization criteria dataset was to the track class provided for the Mountain Subdivision within the VANC-CGY corridor (Table 2-1). In their original data, CP assigned the Mountain Subdivision a track class classification of '4/3', signifying a combination of Class 3 and Class 4 track. However, without information on the relative proportion of Class 3 and Class 4 track, it was not possible to determine which Class was the most prevalent (as was done for CN subdivisions). As such, CaRRL assumed a conservative stance and assigned a Class 3 track class designation, which was also confirmed with CP.

Figures 2-3 through 2-6 present the 2016 train miles, 2016 train counts, subdivision control method breakdown, and subdivision track class breakdown for each corridor in Table 2-1. The order of corridors along the x-axis in Figures 2-3 through 2-6 has been modified from Figures 2-1 and 2-2 to reflect a decreasing trend in the amount of 2016 train miles.

Figures 2-3 and 2-4 clearly show an association between corridors exhibiting large 2016 train miles and large 2016 train counts. However, as demonstrated by the CN NOR-ON and CN SOU-ON corridors, noticeable exceptions can be related to variability in the physical size of each corridor. Two hypothetical corridors with equivalent train counts may present with dramatically different train miles due to the physical size of the corridor and the distance individual trains must travel. The train control (Figure 2-5) and track class (Figure 2-6) distributions are also similar to one another as the CTC subdivisions often comprise Class 4. Finally, comparing Figures 2-3 and 2-5 clearly shows that the majority of corridors containing OCS or MIXED track are also those with the lowest number of 2016 train miles. MIXED track contains a combination of track either existing automatic block system (ABS) train control and either CTC or OCS

systems. As no subdivisions were uniquely ABS controlled, ABS does not have its own classification within Figure 2-5.

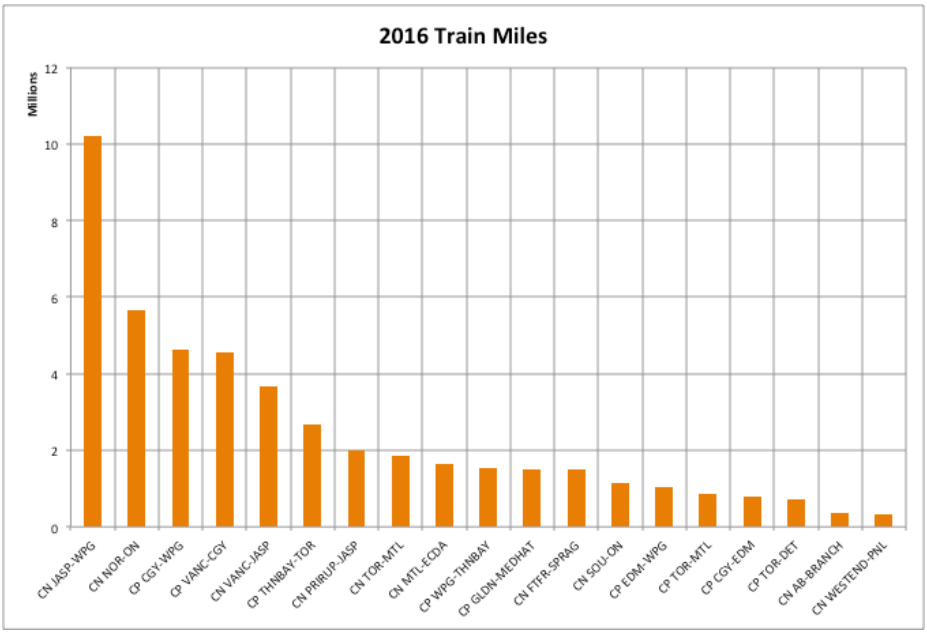

Figure 2-3. 2016 train miles within each corridor.

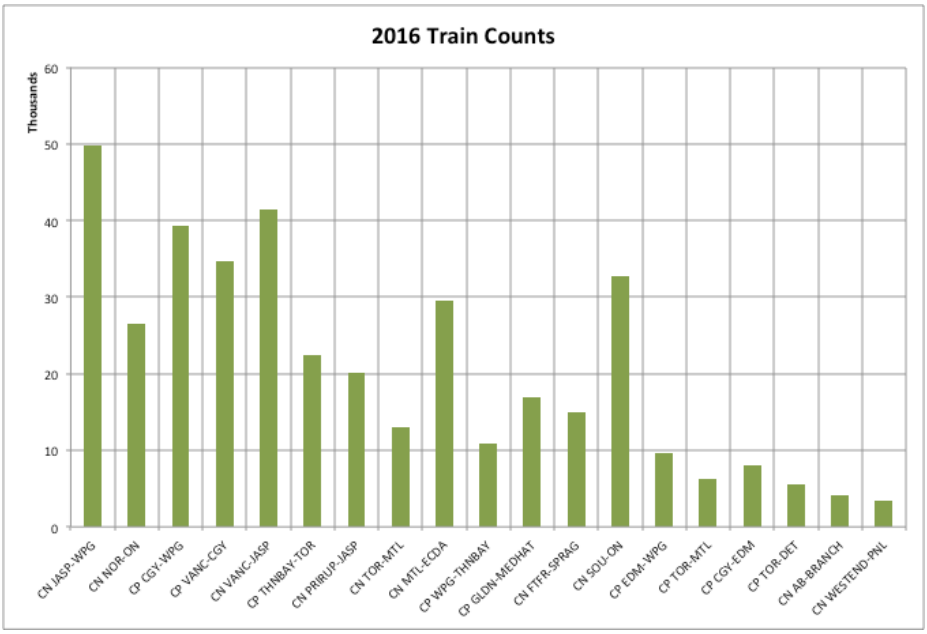

Figure 2-4. 2016 train counts within each corridor.

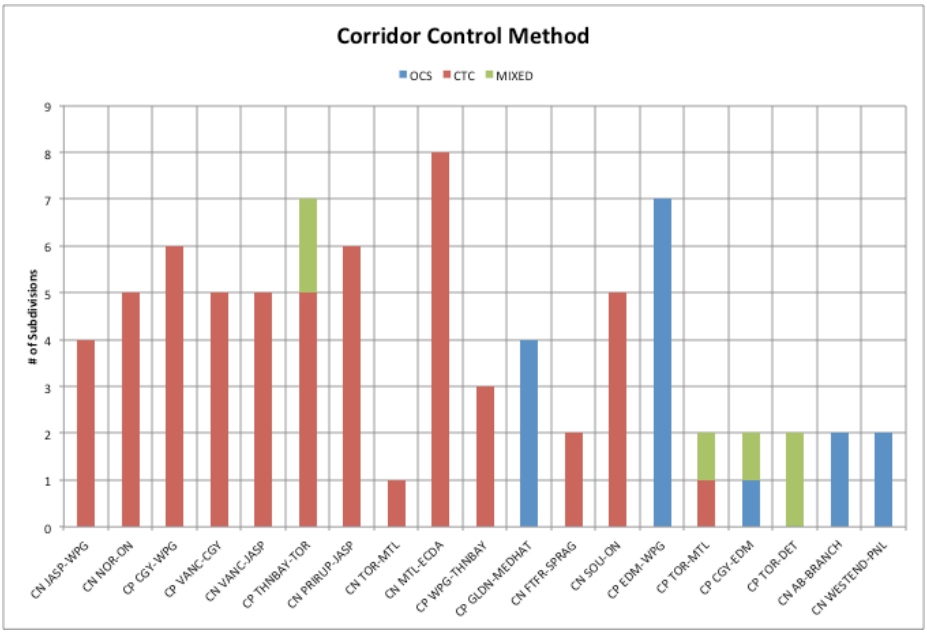

Figure 2-5. Breakdown in control method by number of subdivisions within each corridor.

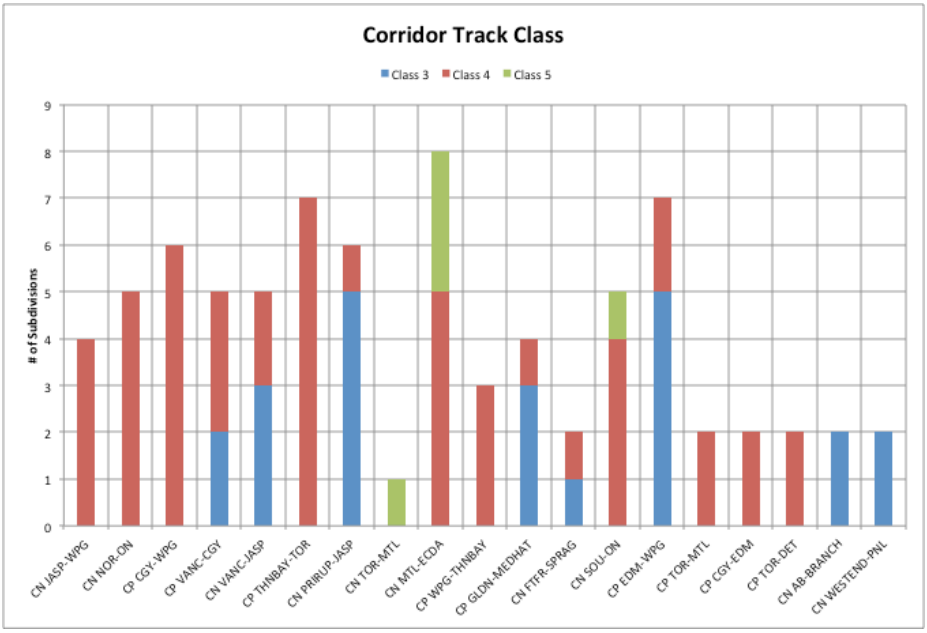

Figure 2-6. Breakdown in track class by number of subdivisions within each corridor.

A point of emphasis when evaluating Figure 2-4 is that the 2016 train counts do not represent the number of unique trains that have traversed each corridor. Due to how the corridor-based data are aggregated from individual subdivisions, a unique train traversing multiple subdivisions within the same corridor will be counted multiple times. An estimate for annual number of

unique trains traversing the individual corridors can be derived by dividing the 2016 train counts (Figure 2-4) by the number of constituent subdivisions (Table 2-1; Figures 2-5 and 2-6).

9.3 Normalization Results

With the normalization criteria defined, the corridor-specific ETC preventability results can be normalized and individual corridors compared. Figures 2-7 and 2-8 present the number of preventable 2007-2016 RODS occurrences at each ETC Level when normalized by 2016 million train miles (Figure 2-7) and thousand train counts (Figure 2-8).

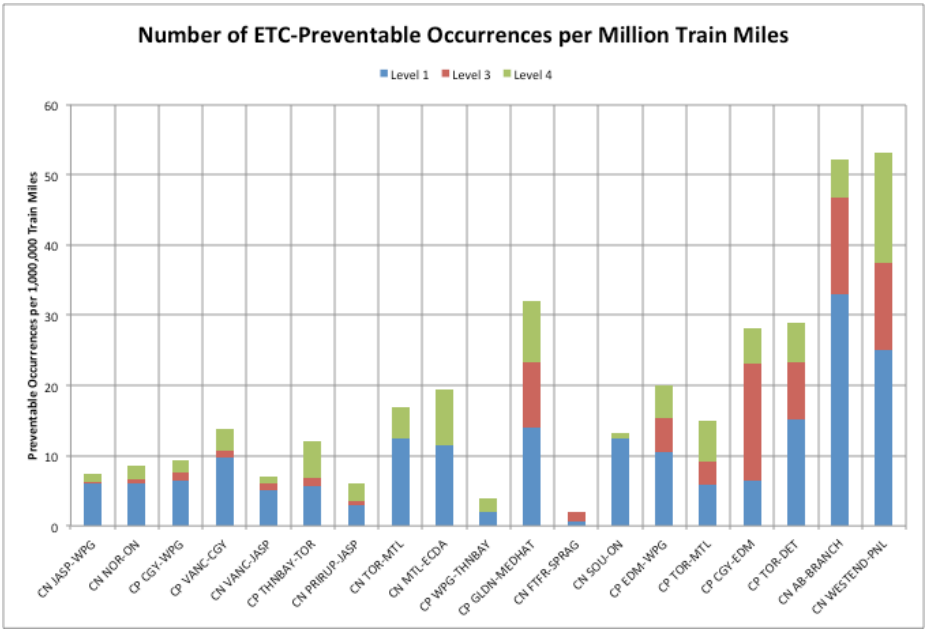

Figure 2-7. Normalized ETC preventable occurrences within each corridor at each ETC Level per million train miles.

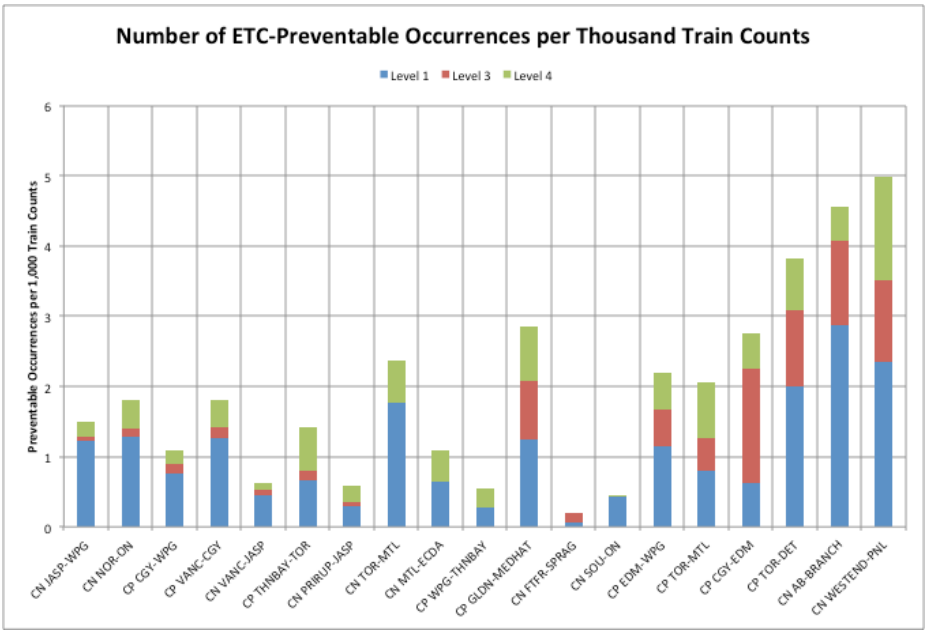

Figure 2-8. Normalized ETC preventable occurrences within each corridor at each ETC Level per thousand train counts.

The normalization results presented in Figures 2-7 and 2-8 are very similar in that the majority of the perceived benefit of ETC (in terms of the number of preventable occurrences) is observed in the corridors on the right-hand side. However, as demonstrated in Figures 2-3 and 2-4, these corridors also exhibit the least traffic (in terms of train miles and train counts). Similarly, these corridors also tend to be associated with subdivisions of OCS or MIXED track (Figure 2-5).

The 2007-2016 ETC preventability results when subdivided by train control method (OCS, CTC, or MIXED) and track class (3, 4, or 5) are tabulated in Tables 2-3 and 2-4, respectively.

Table 2-3. Breakdown of ETC preventability by subdivision control method.

Control Method	Total # of Occurrences	# of ETC-Preventable Occurrences @			# of Non-ETC-Preventable Occurrences
		Level 1	Level 3	Level 4	
OCS	1168	54	88	117	1051
CTC	6932	264	287	373	6559
MIXED	604	24	41	56	548

Table 2-4. Breakdown of ETC preventability by subdivision track class.

Track Class	Total # of Occurrences	# of ETC-Preventable Occurrences @			# of Non-ETC-Preventable Occurrences
		Level 1	Level 3	Level 4	
Class 3	1346	81	110	141	1205
Class 4	6809	221	266	345	6464
Class 5	549	40	40	60	489

A clear difference exists between the proportion of RODS occurrences on CTC and Class 4 track vs. the remaining control methods and track classes. Occurrences on CTC track account for 79.6% of all RODS occurrences, while the proportion occurring along Class 4 track is 78.2%. This is a consequence of the strong correlation between CTC and Class 4 track (Figures 2-5 and 2-6) within individual subdivisions.

With the control method (Table 2-3) and track class (Table 2-4) normalization results dominated by CTC and Class 4 track as well as the train miles (Figure 2-7) and train counts (Figure 2-8) results suggesting the greatest relative ETC benefit would be observed in the corridors experiencing the least amount of traffic (therefore not truly indicative of the *overall* safety benefit or practicality), CaRRL adopted a risk-based approach to evaluating the potential safety benefits to be gained with the proposed ETC system in keeping with the mandate provided by Transport Canada.

10 Multi-Method Approach to Assess the Impact of ETC on Rail Transport Risk

Rail transport risk is a function of the frequency of occurrences and their consequences, which, in turn, are a function of exposure and vulnerability of people, environment, assets, and impacts to rail traffic. These depend on the particular characteristics of any given section of rail; however, some severity indicators can be adopted to increase homogeneity when analyzing the impact of ETC implementation on rail transport risk.

The severity indicators were obtained directly from the RODS database. The indicators selected must be readily available for all occurrences (included in RODS) and provide a good representation of the potential consequences to equipment, the environment, and health and safety. The indicators selected are:

1. Number of rolling stock involved in the occurrences;
2. Number of rolling stock derailed in the occurrences;
3. Number of cars involved that were transporting dangerous goods;
4. Number of occurrences with serious injuries; and
5. Number of fatalities.

These, together with the frequency of occurrences, are the basis for analyzing the impact of ETC on rail transport risk. The selected severity indicators enable the risk evaluation methodology to:

- Take advantage of the large RODS database to assess occurrence frequencies with statistical confidence;
- Take due consideration of the particular characteristics of the sections being analyzed;
- Provide a framework for future assessments regarding the impact of ETC implementation or other methods for enhancing rail transport safety; and
- Provide a means for validation and enhancement between different methods adopted.

A multi-method approach was selected to fulfill these criteria, including a statistically-based evaluation of mainline expected frequency and severity of occurrences and their reduction after ETC implementation, an evaluation of ETC preventability of previous occurrences along

selected rail sections, the basis for a semi-quantitative ranking based on selected risk factors and expert elicitation, and a review and discussion of selected occurrences.

The methods adopted and their justification are summarized in Table 2-5.

Table 2-5. Methods used to evaluate the impact of ETC on rail transport risk.

Method	Brief summary	Advantage	Limitations
Normalized ratios	Normalized, average occurrence frequencies (per year, mile, and train traffic) applied to the section under analysis.	Allows use of the large statistical database in RODS.	Assumes homogeneous track conditions for each class of track and method of control.
Analysis of factual occurrences within the section	Occurrences analyzed for ETC preventability are those within the section under analysis.	Accounts for the particular characteristics of the section being analyzed.	Limited number of occurrences within a given section does not allow statistical approaches.
Risk factors (discussed)	Experience-based, weighted ranking of factors impacting the level of risk along the section.	Allows for eliciting the experience of operators. Can be a basis for future prioritization for ETC implementation.	Does not allow for direct evaluation of ETC preventability.
Review of selected occurrences	Review of a subset of occurrences along the section, investigated by the TSB, with respect to their ETC preventability.	Allows review of occurrences with high or potentially high consequences.	Qualitative evaluation, so care must be taken that the occurrence reflects operational conditions.

The data provided and available at the time of this report are the following:

- RODS database;
- Enhancement of RODS identifying occurrence groups (Part A of the study) and ETC preventability; and
- Track length, train starts, train miles, method of control, and class of track per subdivision (CN and CP mainlines only).

The following sections present the details of the procedures followed for each of the methodologies, the results obtained, and a discussion of the outcomes.

11 Normalized Ratios of Severity Indicators and Example Application

11.1 Severity Indicators over All RODS Data and ETC Preventability

The RODS database for 2007 to 2016 inclusive consists of 14,036 occurrences. RODS further includes information on the selected severity indicators, including the number of rolling stock involved in the occurrence, number of dangerous goods cars involved, number of rolling stock derailed, occurrences with serious injuries, and number of fatalities. CaRRL determined these severity indicators provided the best information available to evaluate potential risks to people, the environment, equipment, and operations. An analysis of severity indicators was done for each occurrence group. These are presented in Table 2-6, with the occurrence groups for which no main-track occurrences have been reported highlighted in red.

Table 2-6. Occurrence groups, with those for which no main-track occurrences have been reported highlighted in red.

Occurrence group
COLLISION INVOLVING TRACK UNIT
CREW MEMBER INCAPACITATED
CROSSING
DERAILMENT INVOLVING TRACK UNIT
DG LEAKER
EMPLOYEE
FIRE
MAIN-TRACK SWITCH IN ABNORMAL POSITION
MAIN-TRACK TRAIN COLLISION
MAIN-TRACK TRAIN DERAILMENT
MOVEMENT EXCEEDS LIMITS OF AUTHORITY
NON-MAIN-TRACK TRAIN COLLISION
NON-MAIN-TRACK TRAIN DERAILMENT
ROLLING STOCK COLLISION WITH ABANDONED VEHICLE
ROLLING STOCK COLLISION WITH OBJECT
ROLLING STOCK DAMAGE WITHOUT DERAILMENT/ COLLISION
RUNAWAY ROLLING STOCK
SIGNAL LESS RESTRICTIVE THAN REQUIRED
TRESPASSER
UNPROTECTED OVERLAP OF AUTHORITIES

Occurrence numbers per group and their preventability after implementation of ETC Levels 1, 3, and 4 are presented in Appendix A inTable A-1. Tables A-2 to A-6 present the total values for

each severity indicator (e.g., total number of rolling stock derailed between 2007 and 2016) and the maximum number of the severity indicator per occurrence where the severity indicator was observed (e.g., maximum number of rolling stock derailed for all occurrences where rolling stock derailed). ETC preventability is also presented and measured in terms of the number of each severity indicator that would have been prevented (e.g., total number of derailed rolling stock that would have not derailed had ETC been implemented) and the percentage of the total number it represents for the severity indicator. Table 2-7 presents a summary of the total number of occurrences and severity indicators as well as their ETC preventability.

Table 2-7. Summary of number of occurrences and severity indicators as well as their ETC preventability.

All RODS Data for 2007-2016			**ETC prev. L1**		**ETC prev. L3**		**ETC prev. L4**	
Severity indicator	**Total**	***Maximum per occurrence**	**No.**	**%**	**No.**	**%**	**No.**	**%**
No. occurrences	14036	NA	498	3.55%	643	4.58%	839	5.98%
Rolling stock involved	28555	86	683	2.39%	863	3.02%	1101	3.86%
Rolling stock derailed	19774	65	169	0.85%	211	1.07%	240	1.21%
Dangerous goods cars involved	3907	72	1	0.03%	6	0.15%	9	0.23%
Occurrences with serious injuries	1687	NA	8	0.47%	8	0.47%	9	0.53%
Fatalities	751	47	3	0.40%	3	0.40%	3	0.40%

* maximum per occurrence where the severity indicator was observed. Not applicable for No. occurrences or No. occurrences with serious injuries (where the maximum per occurrence would be 1).

ETC occurrence preventability ranges between 3.5% for ETC Level 1 and 6% for Level 4. However, occurrence types vary and are associated with different potential consequence magnitudes. The relative change in each severity indicator with successive levels of ETC implementation provides a good estimation of the effectiveness of ETC in reducing transportation risk. Implementation of ETC would have prevented almost 4% of all occurrences involving rolling stock. Further, just over 1% of derailed cars and less than 1% of fatalities, occurrences with serious injuries, or dangerous goods cars would have been prevented with the highest level of ETC between 2007 and 2016. Note that such statistics assume ETC technology was implemented on every train movement and fully operational at all times.

Although ETC has a very small impact on overall preventability when considering the full, ten year (2007-2016) RODS database, ETC implementation would have prevented significant

proportions of occurrences in specific occurrence groups. For example 20% of the 54 main-track collisions and approximately 40% of the 1168 MELA occurrences would have been preventable with the proposed Level 1 functionality. Further implementation of the ETC Level 4 functionality would have prevented 60% of 1168 MELA occurrences and 80% of the 82 main-track switches in abnormal position. The proposed ETC functionality would have successfully prevented incidents within the specific occurrence categories where it was intended to be beneficial; however, these occurrence categories comprise only a small proportion of the overall RODS database.

From a severity perspective, ETC Level 1 implementation would have prevented 50% of derailed rolling stock following a main-track collision (111 cars of 213), even when overall preventability of derailment is low (Table 2-7). Preventability of dangerous goods cars involved is also low per occurrence group, with a maximum of 15% preventability (3 cars out of 20 involved) for main-track collisions if ETC Level 4 had been implemented. Only 6% of fatalities following a main-track derailment would have been prevented by ETC implementation (3 of 52 at ETC Level 1). Most fatalities (over 90%) between 2007 and 2016 follow crossing accidents (233/751) or trespasser incidents (452/751) .

11.2 Ratios of Severity Indicators per Occurrence – Based on All RODS Data for 2007-2016

Ratios of the severity indicators per occurrence are derived as described in Table 2-8. The development of these ratios used the complete RODS database for 2007-2016 to allow for statistically adequate ratios for each occurrence group. This maximizes the use of statistical data and considers the differences between main-track transport and other operations through differentiation per occurrence groups (e.g., main-track as opposed to non-main-track derailments and collisions).

Table 2-8. Ratios of severity indicators per occurrence.

Code	Ratio of severity indicator	Calculation method (over all RODS data from 2007-2016)
RSi	Number of rolling stock involved per occurrence	No. rolling stock involved/ No. occurrences
RSd	Number of rolling stock derailed	No. rolling stock derailed/ No. occurrences
DGCi	Number of dangerous goods cars involved	No. dangerous goods cars involved/ No. occurrences
Inj	Number of occurrences with serious injuries	No. occurrences with serious injuries/ No. occurrences
Fa	Number of fatalities	No. fatalities/ No. occurrences

The ratios of severity indicators are presented in Table 2-9. These represent the statistical frequency of each severity indicator (e.g., number of rolling stock involved, number of occurrences with serious injuries) per occurrence. Values of zero indicate no severity indicators were reported between 2007 and 2016, suggesting their low likelihood. However, this does not necessarily indicate a zero probability; these ratios are indicated by the term "no data".

Table 2-9 suggests some occurrence groups have a higher criticality than others when considering the severity associated with their occurrence. In terms of fatalities and serious injuries, crossing accidents and trespasser incidents show consistently high ratios of severity per occurrence (occurrences where crew is incapacitated or employee injuries show high rates of serious injuries because of the nature of the report). As previously discussed, these account for over 90% of fatalities. Main-track derailments follow with a ratio of fatalities per occurrence (0.054) that is one order of magnitude lower than crossing accidents and trespasser incidents. Main-track train collisions show a high ratio of occurrences with reported serious injuries, following trespasser incidents and crossings.

Regarding the number of rolling stock involved or derailed, main-track collisions and derailments have rates well above average (6 rolling stock involved per occurrence for each, with an average per all occurrences of 2). Considering that main-track speeds are considerably higher than non-main-track operations, collisions and derailments on main track would be associated with increased consequences.

Table 2-9. Ratios of severity indicators per occurrence group.

All RODS Data for 2007-2016		RSi	RSd	DGCi	Inj	Fa
Occurrence group	**No. occurrences**	**Rolling stock involved per occurrence**	**Rolling stock derailed per occurrence**	**Dangerous goods cars per occurrence**	**Ratio of occurrences with serious injuries**	**Fatalities per occurrence**
COLLISION INVOLVING TRACK UNIT	235	2.081	0.115	0.009	0.132	No Data
CREW MEMBER INCAPACITATED	16	1.000	No Data	0.063	0.938	No Data
CROSSING	1912	1.194	0.152	0.066	0.389	0.122
DERAILMENT INVOLVING TRACK UNIT	129	1.070	1.039	0.008	0.023	No Data
DG LEAKER	699	1.000	0.001	1.000	0.010	No Data
EMPLOYEE	101	1.149	0.040	0.079	1.000	0.099
FIRE	241	1.087	0.004	0.025	0.058	No Data
MAIN-TRACK SWITCH IN ABNORMAL POSITION	82	1.049	0.012	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	54	6.056	3.944	0.370	0.130	No Data
MAIN-TRACK TRAIN DERAILMENT	964	6.305	6.166	0.742	0.013	0.054
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1168	1.047	0.002	No Data	0.001	No Data
NON-MAIN-TRACK TRAIN COLLISION	978	3.053	1.059	0.586	0.014	0.001
NON-MAIN-TRACK TRAIN DERAILMENT	6091	1.973	1.968	0.273	0.002	0.0002
ROLLING STOCK COLLISION WITH ABANDONED VEHICLE	94	1.223	0.245	No Data	0.032	0.011
ROLLING STOCK COLLISION WITH OBJECT	210	1.310	0.310	0.033	0.052	0.005
ROLLING STOCK DAMAGE WITHOUT DERAILMENT/ COLLISION	149	1.416	No Data	0.336	0.013	No Data
RUNAWAY ROLLING STOCK	123	3.325	0.341	0.268	0.008	No Data
SIGNAL LESS RESTRICTIVE THAN REQUIRED	21	1.095	No Data	No Data	No Data	No Data
TRESPASSER	711	1.015	No Data	0.001	0.994	0.636
UNPROTECTED OVERLAP OF AUTHORITIES	58	1.345	No Data	No Data	No Data	No Data
Total	**14036**	**2.034**	**1.409**	**0.278**	**0.120**	**0.054**

11.3 Normalized Occurrence Frequency and Severity Indicators – CN and CP Mainline over 10 MGT

ETC implementation was evaluated for rail transport on mainline track. CN and CP provided lengths, train counts, and train miles for mainline operations in Canada with traffic over 10 MGT (as of 2016). With this information, the analysis further focused on occurrences that would reflect operations on CN and CP mainlines with over 10 MGT per year. This corresponded to 4,410 occurrences from 2007 to 2016 inclusive. Occurrences and severity indicators were normalized per unit of time, length, and traffic. The metric selected for normalization was per year and train-mile. Table 2-10 shows the metrics used in the analysis.

Table 2-10. Metrics used for the normalized ratio analysis.

Code	Severity indicator	Normalization
Oc_n	Number of occurrences	No. occurrences/ (year × train mile)
RSi_n	Number of rolling stock involved	(Oc_n) × RSi
RSd_n	Number of rolling stock derailed	(Oc_n) × RSd
DGCi_n	Number of dangerous goods cars involved	(Oc_n) × DGCi
Inj_n	Number of occurrences with serious injuries	(Oc_n) × Inj
Fa_n	Number of fatalities	(Oc_n) × Fa

The characteristics of rail operations vary significantly across the network. Adequate occurrence ratios need to consider the particular characteristics of the railway sections being analyzed. Adopting several groups to better characterize some railway sections will significantly limit the number of occurrences and a balance needs to be found between adequate grouping and maximizing the statistical database in RODS. Two approaches were adopted for grouping the RODS database: 1) class of track and 2) method of control. Table 2-11 presents the data for each of the groups considered.

In Table 2-11, track Classes 4 and 5 were combined into one group due to the limited length of track Class 5 when compared to Classes 3 and 4. Methods of control considered only include OCS and CTC.

Table 2-11. RODS groups for the scale ratio analysis.

Grouping per class of track			
Group	**Track length (miles)**	**Train miles (2016)**	**Occurrences (2007-2016)**
Class 3	2,617.4	8,341,840.1	832
Classes 4 and 5	7,554.4	38,322,353.1	3,578
Grouping per method of control			
Group	**Track length (miles)**	**Train miles (2016)**	**Occurrences (2007-2016)**
OCS	1,826.3	3,642,602.8	643
CTC	7,670.0	40,927,112.0	3,398

The normalized frequency of occurrences per class of track and per occurrence group are presented in Tables A-7 and A-8. The normalized frequency of occurrences per method of control and per occurrence group are presented in Tables A-9 and A-10. Table 2-12 presents a summary of the normalized frequency of occurrences.

Table 2-12. Summary of normalized occurrence frequencies per class of track and method of control.

Group	**No. occurrences**	**Occurrences per year, per million train miles (Oc_n)**
Per class of track		
Track Class 3	832	10.0
Track Classes 4 and 5	3,578	9.3
Per method of control		
OCS	643	18.0
CTC	3,398	8.3

Annual number of occurrences per million train miles is slightly higher for track Class 3 than for Classes 4 and 5; however, the difference is less than 10%. Differences in number of occurrences are evident between different methods of control. Annual number of occurrences per million train miles in OCS territory is more than two times (217%) that in CTC territory.

Table 2-13 provides a summary of the ETC preventability by severity indicator previously presented in Table 2-7. These data are used to calculate ETC preventability by class of track and method of control in Tables 2-14 through 2-17.

Table 2-13. ETC preventability by severity indicator.

ETC Preventability	ETC prev. L1	ETC prev. L3	ETC prev. L4
Severity indicator	**%**	**%**	**%**
No. occurrences	3.55%	4.58%	5.98%
Rolling stock involved	2.39%	3.02%	3.86%
Rolling stock derailed	0.85%	1.07%	1.21%
Dangerous goods cars involved	0.03%	0.15%	0.23%
Occurrences with serious injuries	0.47%	0.47%	0.53%
Fatalities	0.40%	0.40%	0.40%

The normalized frequency of severity indicators per year and per train mile for the grouped classes of track and method of control are shown in Tables A-11 through A-30. These tables also show their expected normalized frequencies after ETC implementation. Tables 2-14 through 2-17 present summaries of the frequency of severity indicators per million train miles and their expected frequencies after ETC implementation. Reductions in some severity indicators in these summary tables are not noticeable because of their small magnitude, but are evident per accident group in the detailed tables in the appendix.

Table 2-14 Frequency of occurrences and severity indicators per year and per million train miles for track Class 3.

Track Class 3	Before ETC	After ETC L1	After ETC L3	After ETC L4
No. occurrences	10	9	8.7	8.3
Rolling stock involved	22	20	20	20
Rolling stock derailed	12	12	12	12
Dangerous goods cars involved	2.4	2.4	2.3	2.3
Occurrences with serious injuries	1.7	1.7	1.7	1.7
Fatalities	0.7	0.7	0.7	0.7

Table 2-15. Frequency of occurrences and severity indicators per year and per million train miles for track Classes 4 and 5.

Track Classes 4 and 5	Before ETC	After ETC L1	After ETC L3	After ETC L4
No. occurrences	9.3	8.7	8.5	8.3
Rolling stock involved	16	15	15	15
Rolling stock derailed	7.1	6.9	6.9	6.8
Dangerous goods cars involved	2.3	2.3	2.3	2.3
Occurrences with serious injuries	2.3	2.3	2.3	2.3
Fatalities	1.1	1.1	1.1	1.1

Table 2-16. Frequency of occurrences and severity indicators per year and per million train miles for OCS method of control.

OCS Method of Control	Before ETC	After ETC L1	After ETC L3	After ETC L4
No. occurrences	18	16	15	14
Rolling stock involved	34	32	31	30
Rolling stock derailed	17	16	16	16
Dangerous goods cars involved	3.5	3.4	3.4	3.4
Occurrences with serious injuries	3.6	3.6	3.6	3.6
Fatalities	1.3	1.3	1.3	1.3

Table 2-17. Frequency of occurrences and severity indicators per year and per million train miles for CTC method of control.

CTC Method of Control	Before ETC	After ETC L1	After ETC L3	After ETC L4
No. occurrences	8.3	7.7	7.6	7.4
Rolling stock involved	15	14	14	14
Rolling stock derailed	7.1	7.0	6.9	6.8
Dangerous goods cars involved	2.2	2.2	2.2	2.2
Occurrences with serious injuries	1.9	1.9	1.9	1.9
Fatalities	0.9	0.9	0.9	0.9

Tables 2-14 through 2-17 suggest modest reductions in the number of occurrences and number of rolling stock involved and derailed after ETC implementation; however, the reduction is not appreciable (and therefore appears not significant) for severity indicators regarding dangerous goods cars involved, serious injuries, and fatalities. When analyzing severity reduction after ETC implementation per occurrence group in Tables A-11 through A-30, reduction in severity indicators mainly occur for main-track collisions and derailments, MELAs, and switches in abnormal positions. Fatalities are mainly reduced only for main-track derailments and collisions.

The ratios in Tables 2-14 through 2-17 can be applied to selected subdivisions to estimate the expected frequency of occurrences and other severity indicators per year, as well as the associated impact of ETC implementation. Information required for the sections analyzed is limited to the number of train miles per year.

11.4 Estimated Severity Indicators for Selected Subdivisions Based on Normalized Ratios – 10-Year Period

The normalized severity indicators (per year and per train mile) were used to estimate the expected values of severity indicators for selected subdivisions. The estimation was done by multiplying the normalized severity indicators by the number of train miles for the subdivision (for the year 2016) and by the selected period of time. The period of time selected was 10 years to provide direct comparison with reported occurrences between 2007 and 2016 inclusive and to avoid excessively small values.

The subdivisions selected for analysis are presented in Table 2-18. These subdivisions were selected to represent the range of track classes, method of control, and train miles for mainline operations with over 10 MGT per year.

Table 2-18. Subdivisions selected for analysis.

Subdivision	Length (miles)	Class of track	Method of control	No. train miles (2016)
Kingston	303	5	CTC	1,838,812.78
Windermere	145	4	OCS	648,943.00
Wynyard	114	3	OCS	187,877.00

Tables A-31 through A-42 present the detailed analysis of expected value of severity indicators, per accident group, for the Kingston subdivision based on normalized ratios and the characteristics of the subdivision. A summary of expected severity indicators is shown in Table 2-19.

Tables A-43 through A-54 present the detailed analysis for the Windermere subdivision and Tables A-55 through A-66 for the Wynyard subdivision. The summaries of expected severity indicators for these subdivisions are presented in Tables 2-20 and 2-21, respectively.

Table 2-19. Estimated severity indicators for the Kingston subdivision based on normalized ratios in the next 10 years.

Kingston subdivision	According to class of track				According to method of control			
Severity indicator	**Before ETC**	**After ETC L1**	**After ETC L3**	**After ETC L4**	**Before ETC**	**After ETC L1**	**After ETC L3**	**After ETC L4**
No. occurrences	171.7	159.2	157.0	152.3	152.7	140.8	139.9	136.0
Rolling stock involved	300.6	284.6	280.7	274.6	280.5	265.5	262.1	256.3
Rolling stock derailed	129.9	127.6	126.3	125.7	130.2	127.8	126.5	125.8
Dangerous goods cars involved	42.5	42.3	42.1	42.1	40.9	40.6	40.5	40.4
Occurrences with serious injuries	41.6	41.5	41.5	41.5	35.2	35.2	35.1	35.1
Fatalities	19.5	19.5	19.5	19.5	16.7	16.7	16.7	16.7

Table 2-20. Estimated severity indicators for the Windermere subdivision based on normalized ratios in the next 10 years.

Windermere subdivision	According to class of track				According to method of control			
Severity indicator	**Before ETC**	**After ETC L1**	**After ETC L3**	**After ETC L4**	**Before ETC**	**After ETC L1**	**After ETC L3**	**After ETC L4**
No. occurrences	60.6	56.2	55.4	53.7	114.6	104.9	98.9	93.7
Rolling stock involved	106.1	100.4	99.1	96.9	218.8	206.7	201.3	196.7
Rolling stock derailed	45.8	45.0	44.6	44.4	107.2	105.4	104.3	103.8
Dangerous goods cars involved	15.0	14.9	14.9	14.8	22.5	22.3	22.2	22.1
Occurrences with serious injuries	14.7	14.7	14.7	14.6	23.2	23.1	23.1	23.1
Fatalities	6.9	6.9	6.9	6.9	8.8	8.7	8.7	8.7

Table 2-21. Estimated severity indicators for the Wynyard subdivision based on normalized ratios in the next 10 years.

Wynyard subdivision	According to class of track				According to method of control			
Severity indicator	**Before ETC**	**After ETC L1**	**After ETC L3**	**After ETC L4**	**Before ETC**	**After ETC L1**	**After ETC L3**	**After ETC L4**
No. occurrences	18.7	16.9	16.3	15.6	33.2	30.4	28.6	27.1
Rolling stock involved	40.6	38.4	37.5	36.6	63.4	59.8	58.3	56.9
Rolling stock derailed	22.9	22.5	22.3	22.2	31.0	30.5	30.2	30.1
Dangerous goods cars involved	4.5	4.4	4.4	4.4	6.5	6.5	6.4	6.4
Occurrences with serious injuries	3.3	3.2	3.2	3.2	6.7	6.7	6.7	6.7
Fatalities	1.4	1.4	1.4	1.4	2.5	2.5	2.5	2.5

Severity indicators estimated for the Kingston subdivision are consistent according to class of track and method of control, with slightly higher values when estimating them according to class of track. Severity indicators along the Windermere and Wynyard subdivisions according to method of control are twice those according to class of track. As expected, severity indicators are higher for the Kingston subdivision than the Windermere and Wynyard subdivisions given traffic density.

These predictions on severity indicators follow the normalized ratios previously discussed and their distribution is not discussed further. Consistent with the assessment of the normalized ratios, implementation of ETC along these subdivisions is not expected to have a significant impact on occurrence frequency, and little to no impact on the number of rolling stock derailed, number of dangerous goods cars involved, number of occurrences with serious injuries, or number of fatalities.

An advantage of this method is that it allows for scenario analysis at any given subdivision regarding variations in method of control, class of track, and traffic density. Moreover, the detail of the calculations (see Tables A-31 through A-66 for the three subdivisions) allow for detailed evaluation of severity indicators per occurrence group.

The limitations of this approach are as follows:

- It homogenizes the operations for the same groups (class of track or method of control) in terms of the percentage of dangerous goods transported with respect to overall goods;
- It does not evaluate differences in severity indicators that could arise from the presence of passenger trains;
- It does not discriminate for route characteristics such as population density, number of crossings and turnouts, and terrain conditions;
- It is highly dependent on the accuracy and completeness of occurrence information reported into the RODS database; and
- Significant potential exists for results to be skewed by one catastrophic ETC-preventable occurrence, especially in corridors with lower occurrence counts.

To overcome these limitations and validate the expected ratios, the reported occurrences along these subdivisions between 2007 and 2016 were also analyzed.

12 Analysis of Occurrences within Selected Subdivisions

The analysis of the three subdivisions was centered around the selected severity indicators and their frequencies given different levels of ETC installed within each subdivision (ETC preventable occurrences are removed from the count for each level of ETC; this assumes perfect performance of the ETC being evaluated). This approach provides a factual analysis of historical occurrences in the period of analysis (2007 to 2016) and assesses which occurrences would have been prevented assuming perfect performance of ETC implementation.

Occurrences and severity indicators between 2007 and 2016 on the selected subdivisions and per occurrence group are shown in Tables A-67 through A-76 (Kingston subdivision), Tables A-77 through A-86 (Windermere subdivision), and Tables A-87 through A-96 (Wynyard subdivision). Tables 2-22 to 2-24 present summaries of the reported severity indicators at the Kingston, Windermere, and Wynyard subdivisions, respectively, as well as their reduction if ETC had been implemented.

Table 2-22. Severity indicators between 2007 and 2016 at the Kingston subdivision and their reduction if ETC had been implemented.

Kingston subdivision	Reported	With ETC L1		With ETC L3		With ETC L4	
		Not prevented	Prevented	Not prevented	Prevented	Not prevented	Prevented
No. occurrences	208	185	11%	185	11%	177	15%
Rolling stock involved	448	420	6%	420	6%	412	8%
Rolling stock derailed	198	197	1%	197	1%	197	1%
Dangerous goods cars involved	59	59	0%	59	0%	59	0%
Occurrences with serious injuries	79	79	0%	79	0%	79	0%
Fatalities	56	56	0%	56	0%	56	0%

Table 2-23. Severity indicators between 2007 and 2016 at the Windermere subdivision and their reduction if ETC had been implemented.

Windermere subdivision	Reported	With ETC L 1		With ETC L 3		With ETC L 4	
		Not prevented	Prevented	Not prevented	Prevented	Not prevented	Prevented
No. occurrences	38	35	8%	33	13%	27	29%
Rolling stock involved	60	57	5%	55	8%	49	18%
Rolling stock derailed	27	27	0%	27	0%	27	0%
Dangerous goods cars involved	2	2	0%	2	0%	2	0%
Occurrences with serious injuries	5	5	0%	5	0%	5	0%
Fatalities	2	2	0%	2	0%	2	0%

Table 2-24. Severity indicators between 2007 and 2016 at the Wynyard subdivision and their reduction if ETC had been implemented.

Wynyard subdivision	Reported	With ETC L 1		With ETC L 3		With ETC L 4	
		Not prevented	Prevented	Not prevented	Prevented	Not prevented	Prevented
No. occurrences	19	18	5%	18	5%	17	11%
Rolling stock involved	60	59	2%	59	2%	58	3%
Rolling stock derailed	42	42	0%	42	0%	42	0%
Dangerous goods cars involved	0	0	NA	0	NA	0	NA
Occurrences with serious injuries	3	3	0%	3	0%	3	0%
Fatalities	1	1	0%	1	0%	1	0%

Reported occurrences and severity indicators on the Kingston subdivision are higher than those predicted by normalized ratios but of the same order of magnitude. Reported occurrences and severity indicators along the Windermere subdivision are lower than those predicted but also of a similar order of magnitude. Reported occurrences and severity indicators at the Wynyard

subdivision are similar to those predicted. This validates the use of normalized ratios, considering the variability of particular subdivisions and the changes these subdivisions would have undergone over the 10 years of record with respect to train density and other operation characteristics.

Occurrence prevention by ETC implementation varies between 5% at the Wynyard subdivision and 11% at the Kingston subdivision for ETC Level 1 implementation, and between 11% at the Wynyard subdivision and 29% at the Windermere subdivision for ETC Level 4 implementation. These are higher preventability values than for the overall RODS database. This can be attributed to the overall RODS preventability analysis reflecting average conditions throughout the network, as opposed to particular railway sections, and that statistically low sample sizes create the potential for higher fluctuations in preventability estimates. When analyzing the preventability of the severity indicators, no fatalities or occurrences with serious injuries would have been prevented. Moreover, only 1% of the rolling stock derailed would have been prevented (for the Kingston subdivision at ETC Level 1), between 2% (Wynyard subdivision) and 6% (Kingston subdivision) of rolling stock involved in occurrences would have been prevented at ETC Level 1, and between 3% (Wynyard subdivision) and 18% (Windermere subdivision) of rolling stock involved in occurrences would have been prevented at ETC Level 4. Consistent with the normalized ratio analysis, this suggests the effect of ETC implementation decreases drastically with the severity of the occurrences. Although ETC implementation would reduce the number of reportable rail occurrences, the extent to which ETC would reduce the critical outcomes appears to be minimal.

13 Risk Factors

In North America, the United States Federal Railroad Administration (FRA) regulates the minimum information requirements to be considered for segment prioritization for the implementation of Positive Train Control (PTC). These are termed "risk factors" in this report, and include information on:

- Passenger volume;
- Freight volume;
- Volume of transported dangerous goods, specifically Toxic by Inhalation (TIH) or Poisonous by Inhalation (PIH) chemicals;
- Method of control;
- Number of tracks;
- Class of track;
- Grade; and
- Curvature.

These minimum requirements focus on the potential for occurrences (grade, curvature, class of track, method of control, transport volumes) and the immediate consequences to rail traffic (passenger transport volumes, freight, and dangerous goods). Other factors can be considered to enhance the ranking of the likelihood of occurrences, to include occurrence mitigation strategies, and to consider the consequences to other elements exposed:

- Presence or absence of wayside detectors, and their types;
- Number of controlled and uncontrolled grade crossings;
- Number of turnouts;
- Presence of high density areas, industrial facilities, critical infrastructure (e.g., hospitals), etc.;
- Occurrence statistics; and
- Sensitive environmental areas (e.g., water bodies, wetlands).

This report presents a discussion of the application of risk factors for prioritization of ETC implementation. The factors highlighted by the FRA consider the importance of operation characteristics such as method of control, class of track, train frequencies, grade, curvature, grade

crossings, and turnouts in evaluating the likelihood of occurrences; this in addition to the importance of passenger volume, amount of transported TIH dangerous goods, presence of populated areas and critical infrastructure, and presence of environmentally sensitive areas when evaluating potential consequences.

Risk factors adopted require consideration of the scope of analysis. It is the view of the authors that comprehensive risk rankings should consider those highlighted by the FRA. At a minimum, a subset of the factors that should be considered for a comprehensive risk ranking are presented in Table 2-25. Each risk factor is given a score based on its value. This value is multiplied by a relative weight, which corresponds to the perceived importance of the factor in the potential for an occurrence and its consequences. Addition over all weighted risk factors renders a risk ranking:

$$\text{Risk Ranking} = \sum_{i=1}^{i=n} Ri \times Wi.$$

Table 2-25. Minimum suggested risk factors for comprehensive risk ranking of rail corridors.

Risk factor	Weight
Passenger volume (R1)	W1
Freight volume (R2)	W2
Volume of dangerous goods (MGT) (R3)	W3
Method of control (R4)	W4
No. of tracks (R5)	W5
Class of track (R6)	W6
Grade and curvature (R7)	W7

Based on the analysis performed on RODS reported occurrences from 2007 to 2016 using the normalized ratios methodology and the evaluation of ETC preventability within selected subdivisions, severity indicators associated with the transport of dangerous goods and risk to life do not appear to be significantly improved after implementation of ETC. In this regard, ranking for prioritization of ETC implementation could be simplified to consider a subset of risk factors (Table 2-26).

Table 2-26. Minimum suggested risk factors for ETC prioritization.

Risk factor	Weight
Train volume (i.e., train miles) (R1 + R2)	W1/2
Method of control (R4)	W4
No. of tracks (R5)	W5
Class of track (R6)	W6
Grade and curvature (R7)	W7

The adoption of Table 2-26 for ETC prioritization, however, should be accompanied by a qualitative evaluation of the amount of dangerous goods transported with respect to exposed population and sensitive environmental areas. This corresponds to the vulnerability of the population and environment to leaks of dangerous goods.

The risk factor analysis for prioritization of ETC implementation should be used as a complement to other methodologies presented in this report, therefore overcoming the limitations of risk factors and other methods. Note that the analysis focuses on the potential for occurrences and their immediate consequences to rail transport, assuming a generic exposure of other elements in the vicinity of the tracks.

14 Review of Selected Occurrences – All RODS 2007 to 2016

A brief summary of selected occurrences from 2007 and 2016 inclusive is presented. Selection criteria correspond to events associated with high consequences. All RODS database (2007-2016) was used, including main-track and non-main-track occurrences. The discussion is centered on ETC preventability for these occurrences. The summary tables are grouped according to severity indicators.

Table 2-27 shows the top 30 occurrences with the largest number of fatalities. These 30 occurrences had two or more reported fatalities, with the exception of one occurrence with one fatality. The list is arranged by number of fatalities, with the event at Lac-Mégantic at the top of the list with 47 fatalities. Only one of these occurrences was identified as ETC preventable, at ETC Level 1, corresponding to the VIA passenger train derailment at Burlington, Ontario in 2012 (TSB report R12T0038). Note this was the only ETC-preventable occurrence with reported fatalities out of 667 between 2007 and 2016, corresponding to 0.15% preventability. This aligns with the fact that over 90% of fatalities follow trespasser and crossing accidents, which are not preventable through ETC implementation as defined for this study (Part A of the report).

Table 2-28 shows the top 30 occurrences with the largest number of cars that released dangerous goods and dangerous goods cars involved. Most of these occurrences correspond to main-track derailments, and the number of dangerous goods cars involved in this summary ranges between 2 and 72 for non-ETC preventable occurrences. The event in Lac-Mégantic is at the top of this list, followed by CN's derailment at Spy Hill, Saskatchewan in 2009 (TSB report R09W0252) in which 22 cars transporting dangerous goods released their content. The 2015 main-track train derailment near Gogama Ontario (R15H0021) is included at the bottom of Table 2-28 for completeness but was absent from the extracted RODS database provided to CaRRL and therefore not included in the ETC assessment.

The only ETC-preventable occurrence in this summary would have been prevented at ETC Level 4. This occurrence involved three dangerous goods cars, two of which released dangerous goods. ETC would not have prevented occurrences between 2007 and 2016 involving larger quantities of released dangerous goods or larger numbers of cars transporting dangerous goods.

Figure 2-27. Top 30 occurrences and associated preventability between 2007 and 2016.

Occurrence No.	Year	Occurrence Group	Locality	Fatalities	ETC Preventable	ETC Level
R13D0054	2013	MAIN-TRACK TRAIN DERAILMENT	LAC-MÉGANTIC	47	No	
R13T0192	2013	CROSSING	OTTAWA	6	No	
R12W0182	2012	CROSSING	BROADVIEW	4	No	
R12T0038	**2012**	**MAIN-TRACK TRAIN DERAILMENT**	**BURLINGTON**	**3**	**Yes**	**1**
R10D0090	2010	TRESPASSER	MONTRÉAL	3	No	
R10E0056	2010	CROSSING	EDMONTON	3	No	
R10W0044	2010	CROSSING	ALLAN	3	No	
R12D0089	2012	TRESPASSER	SAINTE-THÉRÈSE	2	No	
R12E0045	2012	TRESPASSER	LINDBROOK	2	No	
R12T0104	2012	CROSSING	BELLE RIVER	2	No	
R13D0001	2013	CROSSING	JOLIETTE	2	No	
R13E0154	2013	CROSSING	WETASKIWIN	2	No	
R13W0030	2013	CROSSING	WHITEWOOD	2	No	
R14D0046	2014	CROSSING	SAINTE-ROSALIE-JONCTION	2	No	
R14T0224	2014	TRESPASSER	FLAMBORO	2	No	
R16E0034	2016	CROSSING	ENTWISTLE	2	No	
R16E0089	2016	CROSSING	TAKO	2	No	
R16M0020	2016	TRESPASSER	MILFORD	2	No	
R16T0059	2016	CROSSING	LONDON	2	No	
R10V0155	2010	CROSSING	FORT NELSON	2	No	
R07E0115	2007	CROSSING	TORLEA	2	No	
R07T0061	2007	CROSSING	GUELPH	2	No	
R07T0208	2007	CROSSING	TORONTO (S. OF NORTH YORK)	2	No	
R08M0002	2008	CROSSING	SAINT-ARSÈNE	2	No	
R08W0230	2008	CROSSING	WHITEWOOD	2	No	
R09V0219	2009	CROSSING	NANAIMO	2	No	
R09W0072	2009	CROSSING	DAFOE	2	No	
R11D0103	2011	TRESPASSER	MONTRÉAL	2	No	
R11M0036	2011	CROSSING	GRAND FALLS	2	No	
R13E0015	2013	CROSSING	PAYNTON	1	No	

Table 2-28. Occurrences and their preventability between 2007 and 2016 with respect to largest number of dangerous goods cars involved and cars that released dangerous goods.

Occurrence No.	Year	Occurrence Group	Locality	Total DG cars involved	Cars that released DG	ETC Preventable	ETC Level
R13D0054	2013	MAIN-TRACK TRAIN DERAILMENT	LAC-MÉGANTIC	72	59	No	
R09W0252	2009	MAIN-TRACK TRAIN DERAILMENT	SPY HILL	22	22	No	
R13E0142	2013	NON-MAIN-TRACK TRAIN DERAILMENT	GAINFORD	13	9	No	
R07W0155	2007	MAIN-TRACK TRAIN DERAILMENT	FORT QU'APPELLE	5	4	No	
R09T0057	2009	NON-MAIN-TRACK TRAIN DERAILMENT	NANTICOKE	10	3	No	
R15C0028	2015	NON-MAIN-TRACK TRAIN DERAILMENT	CARSELAND	7	3	No	
R13E0015	2013	CROSSING	PAYNTON	16	2	No	
R13T0060	2013	MAIN-TRACK TRAIN DERAILMENT	WHITE RIVER	8	2	No	
R08W0058	**2008**	**MAIN-TRACK TRAIN COLLISION**	**WEYBURN**	**3**	**2**	**Yes**	**4**
R15H0013	2015	MAIN-TRACK TRAIN DERAILMENT	GLADWICK	29	*19	No	
R12W0013	2012	CROSSING	GLEN EWEN	22	1	No	
R14W0256	2014	MAIN-TRACK TRAIN DERAILMENT	CLAIR	6	1	No	
R10D0088	2010	MAIN-TRACK TRAIN COLLISION	CORNWALL	6	1	No	
R10E0116	2010	MAIN-TRACK TRAIN DERAILMENT	PRENTISS	6	1	No	
R09Q0030	2009	NON-MAIN-TRACK TRAIN DERAILMENT	QUÉBEC	5	1	No	
R13W0145	2013	MAIN-TRACK TRAIN DERAILMENT	JANSEN	5	1	No	
R13D0037	2013	NON-MAIN-TRACK TRAIN COLLISION	MONTRÉAL	4	1	No	
R11V0151	2011	MAIN-TRACK TRAIN	CHETWYND	4	1	No	

		DERAILMENT					
R11E0052	2011	NON-MAIN-TRACK TRAIN DERAILMENT	EDMONTON	2	1	No	
R15W0020	2015	NON-MAIN-TRACK TRAIN COLLISION	MELVILLE	30	0	No	
R12W0052	2012	NON-MAIN-TRACK TRAIN DERAILMENT	ATWATER	22	0	No	
R15M0034	2015	MAIN-TRACK TRAIN DERAILMENT	SAINT-BASILE	20	0	No	
R14W0204	2014	CROSSING	CARON	20	0	No	
R14W0158	2014	MAIN-TRACK TRAIN DERAILMENT	CARON	19	0	No	
R14E0081	2014	MAIN-TRACK TRAIN DERAILMENT	FAUST	17	0	No	
R15H0020	2015	MAIN-TRACK TRAIN DERAILMENT	MINNIPUKA	16	0	No	
R14T0160	2014	MAIN-TRACK TRAIN DERAILMENT	BROCKVILLE	13	0	No	
R14W0078	2014	CROSSING	MORTLACH	12	0	No	
R14M0002	2014	MAIN-TRACK TRAIN DERAILMENT	PLASTER ROCK	12	0	No	
R15C0012	2015	MAIN-TRACK TRAIN DERAILMENT	FRANK	12	0	No	
†R15H0021	2015	MAIN_TRACK TRAIN DERAILMENT	GOGAMA	39	33	n/a	n/a

*Obtained from TSB Incident Report R15H0013. All other values from RODS database.
†Record missing from the extracted RODS database provided to CaRRL by the TSB.

Table 2-29 shows the top 35 occurrences with the largest number of rolling stock involved and rolling stock derailed. Rolling stock involved ranged between 30 and 86 and number of rolling stock derailed ranged between 29 and 65 for the top 35 occurrences. Most of these occurrences correspond to derailments on main track. As with Table 2-28, the 2015 Gogama derailment (R15H0021) is included for completeness but was not part of the ETC assessment.

Only two of the occurrences in this summary were ETC preventable, both at ETC Level 1. The number of rolling stock involved in these two ETC preventable occurrences were 34 and 43 and

the number of rolling stock derailed were 29 and 34. ETC implementation would have successfully prevented these occurrences with large numbers of derailed cars. Note that, overall, ETC would have only prevented less than 4% of incidents with rolling stock involved and just over 1% of incidents with rolling stock derailed between 2007 and 2016 (all main-track and non-main-track occurrences).

Table 2-29. Occurrences and their preventability between 2007 and 2016 with respect to the largest number of rolling stock involved and rolling stock derailed.

Occurrence No.	Year	Occurrence Group	Locality	No. Rolling stock involved	No. Rolling stock derailed	ETC Preventable	ETC Level
R13D0054	2013	MAIN-TRACK TRAIN DERAILMENT	LAC-MÉGANTIC	86	65	No	
R10W0031	2010	MAIN-TRACK TRAIN DERAILMENT	RIVERS	57	57	No	
R07M0031	2007	MAIN-TRACK TRAIN DERAILMENT	ST. LEONARD	55	55	No	
R11T0079	2011	MAIN-TRACK TRAIN DERAILMENT	MAKWA	49	49	No	
R12V0036	2012	MAIN-TRACK TRAIN DERAILMENT	SMITHERS	48	48	No	
R08E0150	2008	MAIN-TRACK TRAIN DERAILMENT	PEERS	48	48	No	
R10E0096	2010	NON-MAIN-TRACK TRAIN COLLISION	SCOTFORD	42	42	No	
R13W0257	2013	MAIN-TRACK TRAIN DERAILMENT	FORT FRANCES	40	40	No	
R07T0010	2007	MAIN-TRACK TRAIN DERAILMENT	GOGAMA	38	37	No	
R09W0252	2009	MAIN-TRACK TRAIN DERAILMENT	SPY HILL	36	36	No	
R15M0034	2015	MAIN-TRACK TRAIN DERAILMENT	SAINT-BASILE	36	36	No	
R14W0078	2014	CROSSING	MORTLACH	36	36	No	
R11V0039	2011	MAIN-TRACK TRAIN DERAILMENT	FORT FRASER	36	36	No	

R14W0137	2014	MAIN-TRACK TRAIN DERAILMENT	FORT FRANCES	35	35	No	
R14W0314	2014	MAIN-TRACK TRAIN DERAILMENT	BOOTH	35	35	No	
R07V0269	2007	MAIN-TRACK TRAIN DERAILMENT	BASQUE	35	35	No	
R11V0257	2011	MAIN-TRACK TRAIN DERAILMENT	MOBERLY	34	34	No	
R14W0201	2014	MAIN-TRACK TRAIN DERAILMENT	WALDECK	34	34	No	
R10V0038	**2010**	**MAIN-TRACK TRAIN COLLISION**	**GOLDEN**	**34**	**34**	**Yes**	**1**
R08Q0028	2008	MAIN-TRACK TRAIN DERAILMENT	QUÉBEC	33	33	No	
R08W0169	2008	MAIN-TRACK TRAIN DERAILMENT	ALLANWATER BRIDGE	33	33	No	
R11V0002	2011	MAIN-TRACK TRAIN DERAILMENT	CROYDON	33	33	No	
R11W0161	2011	CROSSING	GRENFELL	33	33	No	
R07T0323	2007	MAIN-TRACK TRAIN DERAILMENT	BRAMPTON	32	32	No	
R07T0060	2007	MAIN-TRACK TRAIN DERAILMENT	KINGSTON	32	32	No	
R10C0086	2010	MAIN-TRACK TRAIN DERAILMENT	AIRDRIE	32	32	No	
R09W0033	2009	MAIN-TRACK TRAIN DERAILMENT	ROBINSON	31	31	No	
R09T0151	2009	MAIN-TRACK TRAIN DERAILMENT	OSHAWA	31	31	No	
R08W0251	2008	MAIN-TRACK TRAIN DERAILMENT	GRAND COULEE	31	31	No	
R12E0008	2012	MAIN-TRACK TRAIN DERAILMENT	FABYAN	31	31	No	
R10E0062	2010	MAIN-TRACK TRAIN DERAILMENT	WILDWOOD	32	30	No	
R07V0248	2007	MAIN-TRACK TRAIN DERAILMENT	GRAND TRUNK	30	30	No	

R09W0007	2009	MAIN-TRACK TRAIN DERAILMENT	MELVILLE	30	30	No	
R11V0109	2011	MAIN-TRACK TRAIN DERAILMENT	ASHCROFT	30	30	No	
R07E0129	**2007**	**MAIN-TRACK TRAIN COLLISION**	**PEERS**	**43**	**29**	**Yes**	**1**
†R15H0021	2015	MAIN_TRACK TRAIN DERAILMENT	GOGAMA	39	33	n/a	n/a

†Record absent from the extracted RODS database provided to CaRRL by the TSB.

15 Strategies for Rail Transport Risk Reduction

The assessment of the impact of ETC implementation on rail transport risk through severity indicators suggests a minor improvement in rail safety in terms of rolling stock derailments and only marginal improvements in decreasing the number of dangerous goods cars involved in occurrences, occurrences with serious injuries, and number of fatalities.

While our research did not identify clear benefits for installation of ETC technologies on any wide-scale basis, it did highlight the potential for other technological areas and risk mitigation strategies that might be worth exploring. The approaches presented in this report, particularly the use of normalized ratios, provide the rationale for not only assessing the effectiveness of ETC implementation but also the impact of implementing other risk reduction techniques.

Some of these rail transport risk reduction techniques worth exploring include:

- *Rail inspection technologies to prevent rail breaks:* Mainline train derailments are one of the occurrence groups associated with the largest numbers of rolling stock involved and derailed as well as number of dangerous goods cars involved. Rail breaks are one of the leading causes of mainline train derailments.
- *Track geometry verification methodologies:* Mainline train derailments are one of the occurrence groups associated with the largest numbers of rolling stock involved and derailed as well as number of dangerous goods cars involved. Track geometry defects are one of the leading causes of mainline train derailments.
- *Interfacing train position with crossing activation to alert oncoming vehicle traffic using Intelligent Traffic Management Systems (ITMS):* One of the leading occurrence groups associated with fatal incidents is crossing accidents. ITMS can first target vehicles associated with a large number of people or potential damage (trucks and buses).
- *Electronic digital transmission of train authorities to eliminate transcription errors:* MELAs can be effectively reduced through implementation of ETC technology.
- *Simplified ETC implementation (Level 1) in key corridors based on risk ranking:* Over half of ETC preventability can be achieved through ETC Level 1 implementation. Most

ETC preventable fatalities and occurrences with serious injuries are achieved at ETC Level 1.

16 Overall Assessment of ETC Implementation on Rail Transport Risk

16.1 Prioritization of ETC Implementation

This report presents and discusses four approaches for prioritizing ETC implementation. These approaches include:

1) statistical treatment of occurrences along the rail network scaled for each corridor or subdivision analyzed;
2) evaluation of reported occurrences and consequences within the corridor or subdivision analyzed;
3) use of risk factors for relative rankings of risk; and
4) the selection of particular, high-profile occurrences.

The authors consider that these four approaches complement each other to provide a comprehensive framework that takes into consideration the statistical recurrence of rail occurrences and their severity as well as ETC preventability, while at the same time considering particular characteristics of the sections being ranked and taking advantage of the experience of operators.

A subset of the approaches presented here can be used for prioritization for the sake of simplification. It is the view of the authors that the statistical approach is validated in this report through the review of factual occurrences for three subdivisions. The strength of this approach lies in its flexibility to model ETC implementation as well as other potential risk mitigation strategies.

The use of risk factors is viewed as a structured, simple approach for eliciting the expertise of rail operators. It is suggested this be complementary to the statistical approach. An important limitation of risk factors is evaluating the effectiveness of risk mitigation strategies in quantitative terms.

16.2 Effectiveness of ETC Implementation in Reducing Rail Transport Risks

This report also presents an overview of ETC preventability in terms of prevention of occurrences and other severity indicators. These include the number of rolling stock involved and derailed in occurrences, the number of dangerous goods cars involved in occurrences, the number of occurrences with serious injuries, and the number of fatalities.

Impact of ETC implementation over all transport operations:

The findings in the report show that ETC occurrence preventability ranges between 3.5% for ETC Level 1 and 6% for Level 4. However, occurrence types are varied and associated with different consequence magnitudes or severity. The reduction in severity indicators provides a better approximation of the impact of ETC implementation on transport risk. Implementation of ETC would have prevented almost 4% of all occurrences involving rolling stock. Further, between 2007 and 2016 just over 1% of derailed cars would have been prevented from derailing, and less than 1% of fatalities, occurrences with serious injuries, or occurrences with dangerous goods cars would have been prevented with the highest level of ETC. Note that such statistics assume ETC technology implemented on every train movement and fully operational at all times.

In terms of occurrence groups, some have a higher criticality than others when considering the severity. In terms of fatalities and serious injuries, crossing accidents and trespasser incidents show consistently high ratios of severity per occurrence[2]. As previously discussed, these account for over 90% of fatalities with a combined fatality per occurrence ratio of 0.758[3]. Main-track derailments have the next highest ratio of fatalities per occurrence at 0.054, which is a full order of magnitude lower.

Regarding the number of rolling stock involved or derailed, main-track collisions and derailments have rates well above average (6 rolling stock involved per occurrence for each, with an average per all occurrences of 2). Considering that main-track speeds are considerably higher

[2] Occurrences where crew members are incapacitated and employee injuries also show high rates of serious injuries due to the nature of the occurrence, but analysis has determined that these occurrences are not ETC preventable.

[3] Fatalities per occurrence after trespasser and crossing accidents between 2007 and 2016 are 0.636 and 0.122, respectively.

than non-main-track operations, collisions and derailments on main track would be associated with increased consequences.

Impact of ETC implementation on mainline rail transport – over 10 MGT:

Ratios of severity indicators for mainline rail transport with over 10 MGT show the same trends. Classifying rail operations per method of control suggests that OCS track has more than twice the number of occurrences per million train miles as CTC track. Reviewing the preventable occurrence rates from the perspective of class of track shows no significant difference between track Classes 3, 4, and 5. When these ratios are applied to selected subdivisions (Kingston, Windermere, and Wynyard used for illustration), the impact of ETC preventability is only noticeable in terms of number of occurrences and number of rolling stock involved and derailed (3.55% up to 5.78% statistical preventability of occurrences and 0.85% up to 2.21% statistical preventability of number of rolling stock derailed for ETC Levels 1 and 4, respectively). Recorded data for the Windermere subdivision show higher occurrence preventability (up to 29% for ETC Level 4), with the preventability of reported rolling stock dropping to zero.

Preventability is significantly reduced to zero or negligible values within these subdivisions for number of dangerous goods cars involved, occurrences with serious injuries, and number of fatalities.

Impact of ETC implementation in reported, high-impact occurrences between 2007 and 2016:

A review of selected occurrences in the RODS database between 2007 and 2016 shows that ETC implementation would not have prevented high-profile occurrences in terms of fatalities, number of dangerous goods cars involved and releasing content, or number of rolling stock derailed. Records show only one ETC-preventable occurrence with reported fatalities out of 667 occurrences with reported fatalities between 2007 and 2016, corresponding to 0.15% preventability. This corresponds to over 90% of fatalities following trespasser and crossing accidents, which are not preventable through ETC implementation as defined for this study (Part A of the report). Most of the high-profile occurrences in terms of number of fatalities and

number of dangerous goods cars with release of content are associated with main-track derailments. ETC would not have prevented the vast majority of these high-profile occurrences.

16.3 ETC Preventability Analysis – Key Findings

In light of the analyses presented here, this section presents key findings regarding the effectiveness of ETC implementation in Canadian federally regulated railway operations. The analyses in this report use the RODS occurrence database, and therefore all analyses performed are based on the accuracy and completeness thereof. ETC preventability assessments are based on the ETC functionality as defined in Part A. Changes to the functionality of the ETC systems will change the results presented here and might influence some of the key findings in this section.

The ETC preventability analysis indicates that ETC implementation has a very minor effect on reducing rail transport risk in terms of fatalities, injuries, and safety in transport of dangerous goods. Although ETC would have prevented a limited subset of occurrences with severe consequences (fatalities and release of dangerous goods) as well as a subset of derailed cars, the results reported here suggest a deeper analysis of other strategies to reduce the severity statistics should be completed when moving towards enhanced rail transport safety in Canada.

In summary, the risk assessment presents some key takeaways:

1. Simple counts of RODS occurrences indicate ETC preventability performance of between 3 and 6% for all RODS occurrences, 37 and 58% for MELA-type occurrences, and 2 and 4% of main-track derailments and collisions;

2. The incremental increase in ETC-preventable occurrences between the ETC Levels is not consistent; the bulk of ETC preventability is associated with the Level 1 functionality;

3. Use of total counts of all RODS occurrences is not the best indicator of relative risk for ETC preventable accidents due to variations in relative severity of incidents by category type as well as relative variances in train volumes and other risk factors (population areas, passenger traffic, etc.);

4. Normalization of RODS occurrences by key operating metrics (such as train counts and train miles) provide a better evaluation of relative risk between rail corridors as well as relative risk under differing operating environments (method of control and track class) but can be misleading if viewed in isolation without adequate consideration of key severity indicators;

5. Evaluation of RODS occurrences and relative corridor risk using normalized data as well as key risk factors and key severity indicator considerations enables improved assessment of overall benefit of ETC implementation between corridors;

6. Occurrence review shows that OCS method of control has more than twice the number of RODS occurrences per million train miles than CTC-equipped track, but this is offset by the significantly lower traffic volumes on OCS corridors;

7. Under any evaluation criteria (raw counts of preventable RODS occurrences, normalized counts of preventable RODS occurrence, or relative risk ranking of corridors based on preventable RODs occurrences), the implementation of ETC technologies has minimal benefits with respect to improving overall safety in any given rail corridor but does show some marginal benefit (20 to 30%) with respect to reducing main-track train-to-train collisions. This is supported by a review of actual occurrences of significant rail accidents over the past 10 years;

8. Review of the RODS occurrence data clearly indicates that some occurrence groups have higher criticality with respect to incident severity than others. Unfortunately, ETC has very limited ability to prevent occurrences in these categories:

    - in terms of fatalities and serious injuries, crossing accidents and trespasser incidents show constantly higher ratios of severity per occurrence;

    - in terms of numbers of all rail cars impacted and dangerous goods rail cars impacted, main-track derailments and main-track collisions have the highest severity per occurrence. With respect to main-track derailments, the highest causal factors relate to rail and track geometry defects, which are not ETC preventable; and

9. Based on the assessment of ETC preventability of RODS occurrences, widespread implementation of the ETC framework established in this study may clearly not be the best approach to improve overall rail safety in Canada. An optimal safety investment strategy would review key causal factors for the most significant severity occurrences. This could highlight other risk mitigation strategies that could be incorporated into a different ETC framework that would be more effective at reducing overall rail transport risk. However, the specifics of additional risk mitigation strategies and an assessment of their ability to prevent additional RODS occurrences is beyond the scope of this assessment.

Appendix A Detailed Tables

Normalized Ratios

Severity Indicators and ETC Preventability for All RODS data from 2007 to 2016

All RODS Number of Occurrences & ETC Preventability			ETC prev. L1		ETC prev. L3		ETC prev. L4	
Occurrence group	No. occurrences	% occurrences from total	No.	%	No.	%	No.	%
COLLISION INVOLVING TRACK UNIT	235	1.67%	7	2.98%	8	3.40%	8	3.40%
CREW MEMBER INCAPACITATED	16	0.11%	0	0.00%	0	0.00%	0	0.00%
CROSSING	1912	13.62%	0	0.00%	0	0.00%	0	0.00%
DERAILMENT INVOLVING TRACK UNIT	129	0.92%	0	0.00%	0	0.00%	0	0.00%
DG LEAKER	699	4.98%	0	0.00%	0	0.00%	0	0.00%
EMPLOYEE	101	0.72%	0	0.00%	0	0.00%	0	0.00%
FIRE	241	1.72%	0	0.00%	0	0.00%	0	0.00%
MAIN-TRACK SWITCH IN ABNORMAL POSITION	82	0.58%	4	4.88%	66	80.49%	66	80.49%
MAIN-TRACK TRAIN COLLISION	54	0.38%	11	20.37%	11	20.37%	17	31.48%
MAIN-TRACK TRAIN DERAILMENT	964	6.87%	11	1.14%	22	2.28%	23	2.39%
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1168	8.32%	463	39.64%	527	45.12%	682	58.39%
NON-MAIN-TRACK TRAIN COLLISION	978	6.97%	0	0.00%	3	0.31%	3	0.31%
NON-MAIN-TRACK TRAIN DERAILMENT	6091	43.40%	0	0.00%	1	0.02%	2	0.03%
R/S COLL. WITH ABANDONED VEHICLE	94	0.67%	0	0.00%	0	0.00%	0	0.00%
R/S COLL. WITH OBJECT	210	1.50%	0	0.00%	1	0.48%	1	0.48%
R/S DAMAGE WITHOUT DERAIL./COLL.	149	1.06%	0	0.00%	0	0.00%	0	0.00%
RUNAWAY ROLLING STOCK	123	0.88%	0	0.00%	0	0.00%	0	0.00%
SIGNAL LESS RESTRICTIVE THAN REQUIRED	21	0.15%	0	0.00%	2	9.52%	20	95.24%
TRESPASSER	711	5.07%	0	0.00%	0	0.00%	0	0.00%
UNPROTECTED OVERLAP OF AUTHORITIES	58	0.41%	2	3.45%	2	3.45%	17	29.31%
Total	**14036**	**100.00%**	**498**	**3.55%**	**643**	**4.58%**	**839**	**5.98%**

Table A-1 All RODS occurrences and ETC preventability (Levels 1, 3 and 4).

All RODS Number of Rolling Stock Involved & ETC Preventability			ETC prev. L1		ETC prev. L3		ETC prev. L4	
Occurrence group	**Total**	**Maximum**	**No.**	**%**	**No.**	**%**	**No.**	**%**
COLLISION INVOLVING TRACK UNIT	489	7	14	2.86%	16	3.27%	16	3.27%
CREW MEMBER INCAPACITATED	16	1	0	0.00%	0	0.00%	0	0.00%
CROSSING	2283	44	0	0.00%	0	0.00%	0	0.00%
DERAILMENT INVOLVING TRACK UNIT	138	3	0	0.00%	0	0.00%	0	0.00%
DG LEAKER	699	1	0	0.00%	0	0.00%	0	0.00%
EMPLOYEE	116	8	0	0.00%	0	0.00%	0	0.00%
FIRE	262	9	0	0.00%	0	0.00%	0	0.00%
MAIN-TRACK SWITCH IN ABNORMAL POSITION	86	3	4	4.65%	70	81.40%	70	81.40%
MAIN-TRACK TRAIN COLLISION	327	43	130	39.76%	130	39.76%	162	49.54%
MAIN-TRACK TRAIN DERAILMENT	6078	86	56	0.92%	89	1.46%	91	1.50%
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1223	6	477	39.00%	541	44.24%	699	57.15%
NON-MAIN-TRACK TRAIN COLLISION	2986	58	0	0.00%	9	0.30%	9	0.30%
NON-MAIN-TRACK TRAIN DERAILMENT	12019	25	0	0.00%	3	0.02%	4	0.03%
R/S COLL. WITH ABANDONED VEHICLE	115	22	0	0.00%	0	0.00%	0	0.00%
R/S COLL. WITH OBJECT	275	11	0	0.00%	1	0.36%	1	0.36%
R/S DAMAGE WITHOUT DERAIL./COLL.	211	26	0	0.00%	0	0.00%	0	0.00%
RUNAWAY ROLLING STOCK	409	78	0	0.00%	0	0.00%	0	0.00%
SIGNAL LESS RESTRICTIVE THAN REQUIRED	23	2	0	0.00%	2	8.70%	22	95.65%
TRESPASSER	722	6	0	0.00%	0	0.00%	0	0.00%
UNPROTECTED OVERLAP OF AUTHORITIES	78	2	2	2.56%	2	2.56%	27	34.62%
Total	**28555**	**86**	**683**	**2.39%**	**863**	**3.02%**	**1101**	**3.86%**

Table A-2 Total number of rolling stock involved between 2007 and 2016, maximum number per occurrence where rolling stock was involved, and ETC preventability as number of rolling stock that would have been prevented from being involved.

All RODS Number of Rolling Stock Derailed & ETC Preventability			ETC prev. L1		ETC prev. L3		ETC prev. L4	
Occurrence group	**Total**	**Maximum**	**No.**	**%**	**No.**	**%**	**No.**	**%**
COLLISION INVOLVING TRACK UNIT	27	3	2	7.41%	3	11.11%	3	11.11%
CREW MEMBER INCAPACITATED	0	0	0	NA	0	NA	0	NA
CROSSING	291	36	0	0.00%	0	0.00%	0	0.00%
DERAILMENT INVOLVING TRACK UNIT	134	2	0	0.00%	0	0.00%	0	0.00%
DG LEAKER	1	1	0	0.00%	0	0.00%	0	0.00%
EMPLOYEE	4	1	0	0.00%	0	0.00%	0	0.00%
FIRE	1	1	0	0.00%	0	0.00%	0	0.00%
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	0	0.00%	1	100.00%	1	100.00%
MAIN-TRACK TRAIN COLLISION	213	34	111	52.11%	111	52.11%	137	64.32%
MAIN-TRACK TRAIN DERAILMENT	5944	65	55	0.93%	90	1.51%	92	1.55%
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	2	1	1	50.00%	1	50.00%	1	50.00%
NON-MAIN-TRACK TRAIN COLLISION	1036	42	0	0.00%	2	0.19%	2	0.19%
NON-MAIN-TRACK TRAIN DERAILMENT	11990	25	0	0.00%	3	0.03%	4	0.03%
R/S COLL. WITH ABANDONED VEHICLE	23	22	0	0.00%	0	0.00%	0	0.00%
R/S COLL. WITH OBJECT	65	11	0	0.00%	0	0.00%	0	0.00%
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	NA	0	NA	0	NA
RUNAWAY ROLLING STOCK	42	5	0	0.00%	0	0.00%	0	0.00%
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	NA	0	NA	0	NA
TRESPASSER	0	0	0	NA	0	NA	0	NA
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	NA	0	NA	0	NA
Total	**19774**	**65**	**169**	**0.85%**	**211**	**1.07%**	**240**	**1.21%**

Table A-3 Total number of rolling stock derailed between 2007 and 2016, maximum number per occurrence where rolling stock was derailed, and ETC preventability as number of rolling stock that would have been prevented from derailing.

All RODS Number of DG cars involved & ETC preventability			ETC prev. L1		ETC prev. L3		ETC prev. L4	
Occurrence group	**Total**	**Maximum**	**No.**	**%**	**No.**	**%**	**No.**	**%**
COLLISION INVOLVING TRACK UNIT	2	1	0	0.00 %	0	0.00%	0	0.00%
CREW MEMBER INCAPACITATED	1	1	0	0.00 %	0	0.00%	0	0.00%
CROSSING	126	22	0	0.00 %	0	0.00%	0	0.00%
DERAILMENT INVOLVING TRACK UNIT	1	1	0	0.00 %	0	0.00%	0	0.00%
DG LEAKER	699	1	0	0.00 %	0	0.00%	0	0.00%
EMPLOYEE	8	8	0	0.00 %	0	0.00%	0	0.00%
FIRE	6	1	0	0.00 %	0	0.00%	0	0.00%
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	NA	0	NA	0	NA
MAIN-TRACK TRAIN COLLISION	20	6	0	0.00 %	0	0.00%	3	15.00 %
MAIN-TRACK TRAIN DERAILMENT	715	72	1	0.14 %	6	0.84%	6	0.84%
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	NA	0	NA	0	NA
NON-MAIN-TRACK TRAIN COLLISION	573	30	0	0.00 %	0	0.00%	0	0.00%
NON-MAIN-TRACK TRAIN DERAILMENT	1665	24	0	0.00 %	0	0.00%	0	0.00%
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	NA	0	NA	0	NA
R/S COLL. WITH OBJECT	7	1	0	0.00 %	0	0.00%	0	0.00%
R/S DAMAGE WITHOUT DERAIL./COLL.	50	10	0	0.00 %	0	0.00%	0	0.00%
RUNAWAY ROLLING STOCK	33	19	0	0.00 %	0	0.00%	0	0.00%
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	NA	0	NA	0	NA
TRESPASSER	1	1	0	0.00 %	0	0.00%	0	0.00%
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	NA	0	NA	0	NA
Total	**3907**	**72**	**1**	**0.03 %**	**6**	**0.15%**	**9**	**0.23 %**

Table A-4 Total number of cars carrying dangerous goods involved in occurrences between 2007 and 2016, maximum number per occurrence where cars carrying dangerous goods were involved, and ETC preventability as number of cars carrying dangerous goods that would have been prevented from being involved.

All RODS No. occurrences with serious injuries & ETC preventability		ETC prev. L1		ETC prev. L3		ETC prev. L4	
Occurrence group	**Total**	**No.**	**%**	**No.**	**%**	**No.**	**%**
COLLISION INVOLVING TRACK UNIT	31	1	3.23%	1	3.23%	1	3.23%
CREW MEMBER INCAPACITATED	15	0	0.00%	0	0.00%	0	0.00%
CROSSING	744	0	0.00%	0	0.00%	0	0.00%
DERAILMENT INVOLVING TRACK UNIT	3	0	0.00%	0	0.00%	0	0.00%
DG LEAKER	7	0	0.00%	0	0.00%	0	0.00%
EMPLOYEE	101	0	0.00%	0	0.00%	0	0.00%
FIRE	14	0	0.00%	0	0.00%	0	0.00%
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	NA	0	NA	0	NA
MAIN-TRACK TRAIN COLLISION	7	4	57.14%	4	57.14%	5	71.43%
MAIN-TRACK TRAIN DERAILMENT	13	3	23.08%	3	23.08%	3	23.08%
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1	0	0.00%	0	0.00%	0	0.00%
NON-MAIN-TRACK TRAIN COLLISION	14	0	0.00%	0	0.00%	0	0.00%
NON-MAIN-TRACK TRAIN DERAILMENT	13	0	0.00%	0	0.00%	0	0.00%
R/S COLL. WITH ABANDONED VEHICLE	3	0	0.00%	0	0.00%	0	0.00%
R/S COLL. WITH OBJECT	11	0	0.00%	0	0.00%	0	0.00%
R/S DAMAGE WITHOUT DERAIL./COLL.	2	0	0.00%	0	0.00%	0	0.00%
RUNAWAY ROLLING STOCK	1	0	0.00%	0	0.00%	0	0.00%
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	NA	0	NA	0	NA
TRESPASSER	707	0	0.00%	0	0.00%	0	0.00%
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	NA	0	NA	0	NA
Total	**1687**	**8**	**0.47%**	**8**	**0.47%**	**9**	**0.53%**

Table A-5 Total number of occurrences with serious injuries between 2007 and 2016 and ETC preventability as number of occurrences with serious injuries that would have been prevented.

All RODS No. Fatalities & ETC preventability			ETC prev. L1		ETC prev. L3		ETC prev. L4	
Occurrence group	**Total**	**Maximum**	**No.**	**%**	**No.**	**%**	**No.**	**%**
COLLISION INVOLVING TRACK UNIT	0	0	0	NA	0	NA	0	NA
CREW MEMBER INCAPACITATED	0	0	0	NA	0	NA	0	NA
CROSSING	233	6	0	0.00%	0	0.00%	0	0.00%
DERAILMENT INVOLVING TRACK UNIT	0	0	0	NA	0	NA	0	NA
DG LEAKER	0	0	0	NA	0	NA	0	NA
EMPLOYEE	10	1	0	0.00%	0	0.00%	0	0.00%
FIRE	0	0	0	NA	0	NA	0	NA
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	NA	0	NA	0	NA
MAIN-TRACK TRAIN COLLISION	0	0	0	NA	0	NA	0	NA
MAIN-TRACK TRAIN DERAILMENT	52	47	3	5.77%	3	5.77%	3	5.77%
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	NA	0	NA	0	NA
NON-MAIN-TRACK TRAIN COLLISION	1	1	0	0.00%	0	0.00%	0	0.00%
NON-MAIN-TRACK TRAIN DERAILMENT	1	1	0	0.00%	0	0.00%	0	0.00%
R/S COLL. WITH ABANDONED VEHICLE	1	1	0	0.00%	0	0.00%	0	0.00%
R/S COLL. WITH OBJECT	1	1	0	0.00%	0	0.00%	0	0.00%
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	NA	0	NA	0	NA
RUNAWAY ROLLING STOCK	0	0	0	NA	0	NA	0	NA
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	NA	0	NA	0	NA
TRESPASSER	452	3	0	0.00%	0	0.00%	0	0.00%
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	NA	0	NA	0	NA
Total	**751**	**47**	**3**	**0.40%**	**3**	**0.40%**	**3**	**0.40%**

Table A-6 Total number of fatalities between 2007 and 2016, maximum number per occurrence where fatalities occurred, and ETC preventability as number of fatalities that would have been prevented.

Normalized Occurrence Frequency per Operation Group – Mainline and Over 10 MGT

Track Class 3		Oc_n
Occurrence group	**No. occurrences**	**Occurrences per year, per train mile**
COLLISION INVOLVING TRACK UNIT	42	5.0E-07
CREW MEMBER INCAPACITATED	2	2.4E-08
CROSSING	207	2.5E-06
DERAILMENT INVOLVING TRACK UNIT	18	2.2E-07
DG LEAKER	63	7.6E-07
EMPLOYEE	6	7.2E-08
FIRE	25	3.0E-07
MAIN-TRACK SWITCH IN ABNORMAL POSITION	18	2.2E-07
MAIN-TRACK TRAIN COLLISION	9	1.1E-07
MAIN-TRACK TRAIN DERAILMENT	148	1.8E-06
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	183	2.2E-06
R/S COLL. WITH ABANDONED VEHICLE	3	3.6E-08
R/S COLL. WITH OBJECT	29	3.5E-07
R/S DAMAGE WITHOUT DERAIL./COLL.	9	1.1E-07
RUNAWAY ROLLING STOCK	10	1.2E-07
SIGNAL LESS RESTRICTIVE THAN REQUIRED	2	2.4E-08
TRESPASSER	43	5.2E-07
UNPROTECTED OVERLAP OF AUTHORITIES	15	1.8E-07
Total	**832**	**1.0E-05**

Table A-7 Normalized occurrence frequency - track Class 3.

Track Classes 4 and 5		Oc_n
Occurrence group	**No. occurrences**	**Occurrences per year, per train mile**
COLLISION INVOLVING TRACK UNIT	116	3.0E-07
CREW MEMBER INCAPACITATED	9	2.3E-08
CROSSING	817	2.1E-06
DERAILMENT INVOLVING TRACK UNIT	67	1.7E-07
DG LEAKER	481	1.3E-06
EMPLOYEE	53	1.4E-07
FIRE	170	4.4E-07
MAIN-TRACK SWITCH IN ABNORMAL POSITION	19	5.0E-08
MAIN-TRACK TRAIN COLLISION	25	6.5E-08
MAIN-TRACK TRAIN DERAILMENT	378	9.9E-07
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	642	1.7E-06
R/S COLL. WITH ABANDONED VEHICLE	61	1.6E-07
R/S COLL. WITH OBJECT	115	3.0E-07
R/S DAMAGE WITHOUT DERAIL./COLL.	104	2.7E-07
RUNAWAY ROLLING STOCK	45	1.2E-07
SIGNAL LESS RESTRICTIVE THAN REQUIRED	11	2.9E-08
TRESPASSER	440	1.1E-06
UNPROTECTED OVERLAP OF AUTHORITIES	25	6.5E-08
Total	**3578**	**9.3E-06**

Table A-8 Normalized occurrence frequency - track Classes 4 and 5.

OCS		Oc_n
Occurrence group	**No. occurrences**	**Occurrences per year, per train mile**
COLLISION INVOLVING TRACK UNIT	23	6.3E-07
CREW MEMBER INCAPACITATED	2	5.5E-08
CROSSING	235	6.5E-06
DERAILMENT INVOLVING TRACK UNIT	9	2.5E-07
DG LEAKER	40	1.1E-06
EMPLOYEE	5	1.4E-07
FIRE	17	4.7E-07
MAIN-TRACK SWITCH IN ABNORMAL POSITION	21	5.8E-07
MAIN-TRACK TRAIN COLLISION	5	1.4E-07
MAIN-TRACK TRAIN DERAILMENT	85	2.3E-06
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	127	3.5E-06
R/S COLL. WITH ABANDONED VEHICLE	4	1.1E-07
R/S COLL. WITH OBJECT	21	5.8E-07
R/S DAMAGE WITHOUT DERAIL./COLL.	7	1.9E-07
RUNAWAY ROLLING STOCK	6	1.6E-07
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0.0E+00
TRESPASSER	24	6.6E-07
UNPROTECTED OVERLAP OF AUTHORITIES	12	3.3E-07
Total	**643**	**1.8E-05**

Table A-9 Normalized occurrence frequency – OCS method of control.

CTC		Oc_n
Occurrence group	**No. occurrences**	**Occurrences per year, per train mile**
COLLISION INVOLVING TRACK UNIT	126	3.1E-07
CREW MEMBER INCAPACITATED	9	2.2E-08
CROSSING	671	1.6E-06
DERAILMENT INVOLVING TRACK UNIT	70	1.7E-07
DG LEAKER	491	1.2E-06
EMPLOYEE	53	1.3E-07
FIRE	151	3.7E-07
MAIN-TRACK SWITCH IN ABNORMAL POSITION	9	2.2E-08
MAIN-TRACK TRAIN COLLISION	29	7.1E-08
MAIN-TRACK TRAIN DERAILMENT	410	1.0E-06
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	629	1.5E-06
R/S COLL. WITH ABANDONED VEHICLE	51	1.2E-07
R/S COLL. WITH OBJECT	110	2.7E-07
R/S DAMAGE WITHOUT DERAIL./COLL.	101	2.5E-07
RUNAWAY ROLLING STOCK	43	1.1E-07
SIGNAL LESS RESTRICTIVE THAN REQUIRED	11	2.7E-08
TRESPASSER	413	1.0E-06
UNPROTECTED OVERLAP OF AUTHORITIES	21	5.1E-08
Total	**3398**	**8.3E-06**

Table A-10 Normalized occurrence frequency – CTC method of control.

Calculated Normalized Frequency of Severity Indicators and ETC Preventability

Track Class 3

Track Class 3 Rolling stock involved	RSi_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	1.0E-06	1.0E-06	1.0E-06	1.0E-06
CREW MEMBER INCAPACITATED	2.4E-08	2.4E-08	2.4E-08	2.4E-08
CROSSING	3.0E-06	3.0E-06	3.0E-06	3.0E-06
DERAILMENT INVOLVING TRACK UNIT	2.3E-07	2.3E-07	2.3E-07	2.3E-07
DG LEAKER	7.6E-07	7.6E-07	7.6E-07	7.6E-07
EMPLOYEE	8.3E-08	8.3E-08	8.3E-08	8.3E-08
FIRE	3.3E-07	3.3E-07	3.3E-07	3.3E-07
MAIN-TRACK SWITCH IN ABNORMAL POSITION	2.3E-07	2.2E-07	4.4E-08	4.4E-08
MAIN-TRACK TRAIN COLLISION	6.5E-07	5.2E-07	5.2E-07	4.5E-07
MAIN-TRACK TRAIN DERAILMENT	1.1E-05	1.1E-05	1.1E-05	1.1E-05
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	2.3E-06	1.4E-06	1.3E-06	9.6E-07
R/S COLL. WITH ABANDONED VEHICLE	4.4E-08	4.4E-08	4.4E-08	4.4E-08
R/S COLL. WITH OBJECT	4.6E-07	4.6E-07	4.5E-07	4.5E-07
R/S DAMAGE WITHOUT DERAIL./COLL.	1.5E-07	1.5E-07	1.5E-07	1.5E-07
RUNAWAY ROLLING STOCK	4.0E-07	4.0E-07	4.0E-07	4.0E-07
SIGNAL LESS RESTRICTIVE THAN REQUIRED	2.6E-08	2.6E-08	2.4E-08	1.3E-09
TRESPASSER	5.2E-07	5.2E-07	5.2E-07	5.2E-07
UNPROTECTED OVERLAP OF AUTHORITIES	2.4E-07	2.3E-07	2.3E-07	1.7E-07
Total	**2.2E-05**	**2.0E-05**	**2.0E-05**	**2.0E-05**

Table A-11 Normalized statistical frequency of rolling stock involved per occurrence and ETC preventability - track Class 3.

Track Class 3 Rolling stock derailed	RSd_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	5.8E-08	5.6E-08	5.6E-08	5.6E-08
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	3.8E-07	3.8E-07	3.8E-07	3.8E-07
DERAILMENT INVOLVING TRACK UNIT	2.2E-07	2.2E-07	2.2E-07	2.2E-07
DG LEAKER	1.1E-09	1.1E-09	1.1E-09	1.1E-09
EMPLOYEE	2.8E-09	2.8E-09	2.8E-09	2.8E-09
FIRE	1.2E-09	1.2E-09	1.2E-09	1.2E-09
MAIN-TRACK SWITCH IN ABNORMAL POSITION	2.6E-09	2.5E-09	5.1E-10	5.1E-10
MAIN-TRACK TRAIN COLLISION	4.3E-07	3.4E-07	3.4E-07	2.9E-07
MAIN-TRACK TRAIN DERAILMENT	1.1E-05	1.1E-05	1.1E-05	1.1E-05
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	3.8E-09	2.3E-09	2.1E-09	1.6E-09
R/S COLL. WITH ABANDONED VEHICLE	8.8E-09	8.8E-09	8.8E-09	8.8E-09
R/S COLL. WITH OBJECT	1.1E-07	1.1E-07	1.1E-07	1.1E-07
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	4.1E-08	4.1E-08	4.1E-08	4.1E-08
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	No Data	No Data	No Data	No Data
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**1.2E-05**	**1.2E-05**	**1.2E-05**	**1.2E-05**

Table A-12 Normalized statistical frequency of rolling stock derailed per occurrence and ETC preventability - track Class 3.

Track Class 3 Dangerous goods cars involved	DGCi_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	4.3E-09	4.2E-09	4.1E-09	4.1E-09
CREW MEMBER INCAPACITATED	1.5E-09	1.5E-09	1.5E-09	1.5E-09
CROSSING	1.6E-07	1.6E-07	1.6E-07	1.6E-07
DERAILMENT INVOLVING TRACK UNIT	1.7E-09	1.7E-09	1.7E-09	1.7E-09
DG LEAKER	7.6E-07	7.6E-07	7.6E-07	7.6E-07
EMPLOYEE	5.7E-09	5.7E-09	5.7E-09	5.7E-09
FIRE	7.5E-09	7.5E-09	7.5E-09	7.5E-09
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	4.0E-08	3.2E-08	3.2E-08	2.7E-08
MAIN-TRACK TRAIN DERAILMENT	1.3E-06	1.3E-06	1.3E-06	1.3E-06
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	No Data	No Data	No Data	No Data
R/S COLL. WITH OBJECT	1.2E-08	1.2E-08	1.2E-08	1.2E-08
R/S DAMAGE WITHOUT DERAIL./COLL.	3.6E-08	3.6E-08	3.6E-08	3.6E-08
RUNAWAY ROLLING STOCK	3.2E-08	3.2E-08	3.2E-08	3.2E-08
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	7.2E-10	7.2E-10	7.2E-10	7.2E-10
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**2.4E-06**	**2.4E-06**	**2.3E-06**	**2.3E-06**

Table A-13 Normalized statistical frequency of dangerous goods cars involved per occurrence and ETC preventability - track Class 3.

Track Class 3 Occurrences with serious injuries	Inj_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	6.6E-08	6.4E-08	6.4E-08	6.4E-08
CREW MEMBER INCAPACITATED	2.2E-08	2.2E-08	2.2E-08	2.2E-08
CROSSING	9.7E-07	9.7E-07	9.7E-07	9.7E-07
DERAILMENT INVOLVING TRACK UNIT	5.0E-09	5.0E-09	5.0E-09	5.0E-09
DG LEAKER	7.6E-09	7.6E-09	7.6E-09	7.6E-09
EMPLOYEE	7.2E-08	7.2E-08	7.2E-08	7.2E-08
FIRE	1.7E-08	1.7E-08	1.7E-08	1.7E-08
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	1.4E-08	1.1E-08	1.1E-08	9.6E-09
MAIN-TRACK TRAIN DERAILMENT	2.4E-08	2.4E-08	2.3E-08	2.3E-08
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1.9E-09	1.1E-09	1.0E-09	7.8E-10
R/S COLL. WITH ABANDONED VEHICLE	1.1E-09	1.1E-09	1.1E-09	1.1E-09
R/S COLL. WITH OBJECT	1.8E-08	1.8E-08	1.8E-08	1.8E-08
R/S DAMAGE WITHOUT DERAIL./COLL.	1.4E-09	1.4E-09	1.4E-09	1.4E-09
RUNAWAY ROLLING STOCK	9.7E-10	9.7E-10	9.7E-10	9.7E-10
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	5.1E-07	5.1E-07	5.1E-07	5.1E-07
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**1.7E-06**	**1.7E-06**	**1.7E-06**	**1.7E-06**

Table A-14 Normalized ratio of occurrences with serious injuries and ETC preventability - track Class 3.

Track Class 3 Fatalities	Fa_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	3.0E-07	3.0E-07	3.0E-07	3.0E-07
DERAILMENT INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
DG LEAKER	No Data	No Data	No Data	No Data
EMPLOYEE	7.1E-09	7.1E-09	7.1E-09	7.1E-09
FIRE	No Data	No Data	No Data	No Data
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN DERAILMENT	9.6E-08	9.5E-08	9.4E-08	9.3E-08
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	3.8E-10	3.8E-10	3.8E-10	3.8E-10
R/S COLL. WITH OBJECT	1.7E-09	1.7E-09	1.6E-09	1.6E-09
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	No Data	No Data	No Data	No Data
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	3.3E-07	3.3E-07	3.3E-07	3.3E-07
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**7.3E-07**	**7.3E-07**	**7.3E-07**	**7.3E-07**

Table A-15 Normalized statistical frequency of fatalities per occurrence and ETC preventability - track Class 3.

Track Classes 4 and 5

Track Classes 4 and 5 Rolling stock involved	**RSi_n per year, per train mile**			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	6.3E-07	6.1E-07	6.1E-07	6.1E-07
CREW MEMBER INCAPACITATED	2.3E-08	2.3E-08	2.3E-08	2.3E-08
CROSSING	2.5E-06	2.5E-06	2.5E-06	2.5E-06
DERAILMENT INVOLVING TRACK UNIT	1.9E-07	1.9E-07	1.9E-07	1.9E-07
DG LEAKER	1.3E-06	1.3E-06	1.3E-06	1.3E-06
EMPLOYEE	1.6E-07	1.6E-07	1.6E-07	1.6E-07
FIRE	4.8E-07	4.8E-07	4.8E-07	4.8E-07
MAIN-TRACK SWITCH IN ABNORMAL POSITION	5.2E-08	4.9E-08	1.0E-08	1.0E-08
MAIN-TRACK TRAIN COLLISION	4.0E-07	3.1E-07	3.1E-07	2.7E-07
MAIN-TRACK TRAIN DERAILMENT	6.2E-06	6.1E-06	6.1E-06	6.1E-06
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1.8E-06	1.1E-06	9.6E-07	7.3E-07
R/S COLL. WITH ABANDONED VEHICLE	1.9E-07	1.9E-07	1.9E-07	1.9E-07
R/S COLL. WITH OBJECT	3.9E-07	3.9E-07	3.9E-07	3.9E-07
R/S DAMAGE WITHOUT DERAIL./COLL.	3.8E-07	3.8E-07	3.8E-07	3.8E-07
RUNAWAY ROLLING STOCK	3.9E-07	3.9E-07	3.9E-07	3.9E-07
SIGNAL LESS RESTRICTIVE THAN REQUIRED	3.1E-08	3.1E-08	2.8E-08	1.5E-09
TRESPASSER	1.2E-06	1.2E-06	1.2E-06	1.2E-06
UNPROTECTED OVERLAP OF AUTHORITIES	8.8E-08	8.5E-08	8.5E-08	6.2E-08
Total	**1.6E-05**	**1.5E-05**	**1.5E-05**	**1.5E-05**

Table A-16 Normalized statistical frequency of rolling stock involved per occurrence and ETC preventability - track Classes 4 and 5.

Track Classes 4 and 5 Rolling stock derailed	RSd_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	3.5E-08	3.4E-08	3.4E-08	3.4E-08
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	3.2E-07	3.2E-07	3.2E-07	3.2E-07
DERAILMENT INVOLVING TRACK UNIT	1.8E-07	1.8E-07	1.8E-07	1.8E-07
DG LEAKER	1.8E-09	1.8E-09	1.8E-09	1.8E-09
EMPLOYEE	5.5E-09	5.5E-09	5.5E-09	5.5E-09
FIRE	1.8E-09	1.8E-09	1.8E-09	1.8E-09
MAIN-TRACK SWITCH IN ABNORMAL POSITION	6.0E-10	5.8E-10	1.2E-10	1.2E-10
MAIN-TRACK TRAIN COLLISION	2.6E-07	2.0E-07	2.0E-07	1.8E-07
MAIN-TRACK TRAIN DERAILMENT	6.1E-06	6.0E-06	5.9E-06	5.9E-06
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	2.9E-09	1.7E-09	1.6E-09	1.2E-09
R/S COLL. WITH ABANDONED VEHICLE	3.9E-08	3.9E-08	3.9E-08	3.9E-08
R/S COLL. WITH OBJECT	9.3E-08	9.3E-08	9.2E-08	9.2E-08
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	4.0E-08	4.0E-08	4.0E-08	4.0E-08
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	No Data	No Data	No Data	No Data
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**7.1E-06**	**6.9E-06**	**6.9E-06**	**6.8E-06**

Table A-17 Normalized statistical frequency of rolling stock derailed per occurrence and ETC preventability - track Classes 4 and 5.

Track Classes 4 and 5 Dangerous goods cars involved	DGCi_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	2.6E-09	2.5E-09	2.5E-09	2.5E-09
CREW MEMBER INCAPACITATED	1.5E-09	1.5E-09	1.5E-09	1.5E-09
CROSSING	1.4E-07	1.4E-07	1.4E-07	1.4E-07
DERAILMENT INVOLVING TRACK UNIT	1.4E-09	1.4E-09	1.4E-09	1.4E-09
DG LEAKER	1.3E-06	1.3E-06	1.3E-06	1.3E-06
EMPLOYEE	1.1E-08	1.1E-08	1.1E-08	1.1E-08
FIRE	1.1E-08	1.1E-08	1.1E-08	1.1E-08
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	2.4E-08	1.9E-08	1.9E-08	1.7E-08
MAIN-TRACK TRAIN DERAILMENT	7.3E-07	7.2E-07	7.1E-07	7.1E-07
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	No Data	No Data	No Data	No Data
R/S COLL. WITH OBJECT	1.0E-08	1.0E-08	1.0E-08	1.0E-08
R/S DAMAGE WITHOUT DERAIL./COLL.	9.1E-08	9.1E-08	9.1E-08	9.1E-08
RUNAWAY ROLLING STOCK	3.2E-08	3.2E-08	3.2E-08	3.2E-08
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	1.6E-09	1.6E-09	1.6E-09	1.6E-09
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**2.3E-06**	**2.3E-06**	**2.3E-06**	**2.3E-06**

Table A-18 Normalized statistical frequency of dangerous goods cars involved per occurrence and ETC preventability - track Classes 4 and 5.

Track Classes 4 and 5 Occurrences with serious injuries	Inj_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	4.0E-08	3.9E-08	3.9E-08	3.9E-08
CREW MEMBER INCAPACITATED	2.2E-08	2.2E-08	2.2E-08	2.2E-08
CROSSING	8.3E-07	8.3E-07	8.3E-07	8.3E-07
DERAILMENT INVOLVING TRACK UNIT	4.1E-09	4.1E-09	4.1E-09	4.1E-09
DG LEAKER	1.3E-08	1.3E-08	1.3E-08	1.3E-08
EMPLOYEE	1.4E-07	1.4E-07	1.4E-07	1.4E-07
FIRE	2.6E-08	2.6E-08	2.6E-08	2.6E-08
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	8.5E-09	6.7E-09	6.7E-09	5.8E-09
MAIN-TRACK TRAIN DERAILMENT	1.3E-08	1.3E-08	1.3E-08	1.3E-08
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1.4E-09	8.7E-10	7.9E-10	6.0E-10
R/S COLL. WITH ABANDONED VEHICLE	5.1E-09	5.1E-09	5.1E-09	5.1E-09
R/S COLL. WITH OBJECT	1.6E-08	1.6E-08	1.6E-08	1.6E-08
R/S DAMAGE WITHOUT DERAIL./COLL.	3.6E-09	3.6E-09	3.6E-09	3.6E-09
RUNAWAY ROLLING STOCK	9.5E-10	9.5E-10	9.5E-10	9.5E-10
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	1.1E-06	1.1E-06	1.1E-06	1.1E-06
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**2.3E-06**	**2.3E-06**	**2.3E-06**	**2.3E-06**

Table A-19 Normalized ratio of occurrences with serious injuries and ETC preventability - track classes 4 and 5.

Track Classes 4 and 5 Fatalities	Fa_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	2.6E-07	2.6E-07	2.6E-07	2.6E-07
DERAILMENT INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
DG LEAKER	No Data	No Data	No Data	No Data
EMPLOYEE	1.4E-08	1.4E-08	1.4E-08	1.4E-08
FIRE	No Data	No Data	No Data	No Data
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN DERAILMENT	5.3E-08	5.3E-08	5.2E-08	5.2E-08
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	1.7E-09	1.7E-09	1.7E-09	1.7E-09
R/S COLL. WITH OBJECT	1.4E-09	1.4E-09	1.4E-09	1.4E-09
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	No Data	No Data	No Data	No Data
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	7.3E-07	7.3E-07	7.3E-07	7.3E-07
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**1.1E-06**	**1.1E-06**	**1.1E-06**	**1.1E-06**

Table A-20 Normalized statistical frequency of fatalities per occurrence and ETC preventability - track Classes 4 and 5.

OCS

OCS Rolling stock involved	RSi_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	1.3E-06	1.3E-06	1.3E-06	1.3E-06
CREW MEMBER INCAPACITATED	5.5E-08	5.5E-08	5.5E-08	5.5E-08
CROSSING	7.7E-06	7.7E-06	7.7E-06	7.7E-06
DERAILMENT INVOLVING TRACK UNIT	2.6E-07	2.6E-07	2.6E-07	2.6E-07
DG LEAKER	1.1E-06	1.1E-06	1.1E-06	1.1E-06
EMPLOYEE	1.6E-07	1.6E-07	1.6E-07	1.6E-07
FIRE	5.1E-07	5.1E-07	5.1E-07	5.1E-07
MAIN-TRACK SWITCH IN ABNORMAL POSITION	6.0E-07	5.8E-07	1.2E-07	1.2E-07
MAIN-TRACK TRAIN COLLISION	8.3E-07	6.6E-07	6.6E-07	5.7E-07
MAIN-TRACK TRAIN DERAILMENT	1.5E-05	1.5E-05	1.4E-05	1.4E-05
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	3.7E-06	2.2E-06	2.0E-06	1.5E-06
R/S COLL. WITH ABANDONED VEHICLE	1.3E-07	1.3E-07	1.3E-07	1.3E-07
R/S COLL. WITH OBJECT	7.5E-07	7.5E-07	7.5E-07	7.5E-07
R/S DAMAGE WITHOUT DERAIL./COLL.	2.7E-07	2.7E-07	2.7E-07	2.7E-07
RUNAWAY ROLLING STOCK	5.5E-07	5.5E-07	5.5E-07	5.5E-07
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TRESPASSER	6.7E-07	6.7E-07	6.7E-07	6.7E-07
UNPROTECTED OVERLAP OF AUTHORITIES	4.4E-07	4.3E-07	4.3E-07	3.1E-07
Total	**3.4E-05**	**3.2E-05**	**3.1E-05**	**3.0E-05**

Table A-21 Normalized statistical frequency of rolling stock involved per occurrence and ETC preventability - OCS method of control.

OCS Rolling stock derailed	RSd_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	7.3E-08	7.0E-08	7.0E-08	7.0E-08
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	9.8E-07	9.8E-07	9.8E-07	9.8E-07
DERAILMENT INVOLVING TRACK UNIT	2.6E-07	2.6E-07	2.6E-07	2.6E-07
DG LEAKER	1.6E-09	1.6E-09	1.6E-09	1.6E-09
EMPLOYEE	5.4E-09	5.4E-09	5.4E-09	5.4E-09
FIRE	1.9E-09	1.9E-09	1.9E-09	1.9E-09
MAIN-TRACK SWITCH IN ABNORMAL POSITION	7.0E-09	6.7E-09	1.4E-09	1.4E-09
MAIN-TRACK TRAIN COLLISION	5.4E-07	4.3E-07	4.3E-07	3.7E-07
MAIN-TRACK TRAIN DERAILMENT	1.4E-05	1.4E-05	1.4E-05	1.4E-05
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	6.0E-09	3.6E-09	3.3E-09	2.5E-09
R/S COLL. WITH ABANDONED VEHICLE	2.7E-08	2.7E-08	2.7E-08	2.7E-08
R/S COLL. WITH OBJECT	1.8E-07	1.8E-07	1.8E-07	1.8E-07
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	5.6E-08	5.6E-08	5.6E-08	5.6E-08
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	No Data	No Data	No Data	No Data
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**1.7E-05**	**1.6E-05**	**1.6E-05**	**1.6E-05**

Table A-22 Normalized statistical frequency of rolling stock derailed per occurrence and ETC preventability - OCS method of control.

OCS Dangerous goods cars involved	DGCi_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	5.4E-09	5.2E-09	5.2E-09	5.2E-09
CREW MEMBER INCAPACITATED	3.4E-09	3.4E-09	3.4E-09	3.4E-09
CROSSING	4.3E-07	4.3E-07	4.3E-07	4.3E-07
DERAILMENT INVOLVING TRACK UNIT	1.9E-09	1.9E-09	1.9E-09	1.9E-09
DG LEAKER	1.1E-06	1.1E-06	1.1E-06	1.1E-06
EMPLOYEE	1.1E-08	1.1E-08	1.1E-08	1.1E-08
FIRE	1.2E-08	1.2E-08	1.2E-08	1.2E-08
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	5.1E-08	4.0E-08	4.0E-08	3.5E-08
MAIN-TRACK TRAIN DERAILMENT	1.7E-06	1.7E-06	1.7E-06	1.7E-06
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	No Data	No Data	No Data	No Data
R/S COLL. WITH OBJECT	1.9E-08	1.9E-08	1.9E-08	1.9E-08
R/S DAMAGE WITHOUT DERAIL./COLL.	6.4E-08	6.4E-08	6.4E-08	6.4E-08
RUNAWAY ROLLING STOCK	4.4E-08	4.4E-08	4.4E-08	4.4E-08
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	9.3E-10	9.3E-10	9.3E-10	9.3E-10
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**3.5E-06**	**3.4E-06**	**3.4E-06**	**3.4E-06**

Table A-23 Normalized statistical frequency of dangerous goods cars involved per occurrence and ETC preventability - OCS method of control.

OCS Occurrences with serious injuries	Inj_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	8.3E-08	8.1E-08	8.0E-08	8.0E-08
CREW MEMBER INCAPACITATED	5.1E-08	5.1E-08	5.1E-08	5.1E-08
CROSSING	2.5E-06	2.5E-06	2.5E-06	2.5E-06
DERAILMENT INVOLVING TRACK UNIT	5.7E-09	5.7E-09	5.7E-09	5.7E-09
DG LEAKER	1.1E-08	1.1E-08	1.1E-08	1.1E-08
EMPLOYEE	1.4E-07	1.4E-07	1.4E-07	1.4E-07
FIRE	2.7E-08	2.7E-08	2.7E-08	2.7E-08
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	1.8E-08	1.4E-08	1.4E-08	1.2E-08
MAIN-TRACK TRAIN DERAILMENT	3.1E-08	3.1E-08	3.1E-08	3.1E-08
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	3.0E-09	1.8E-09	1.6E-09	1.2E-09
R/S COLL. WITH ABANDONED VEHICLE	3.5E-09	3.5E-09	3.5E-09	3.5E-09
R/S COLL. WITH OBJECT	3.0E-08	3.0E-08	3.0E-08	3.0E-08
R/S DAMAGE WITHOUT DERAIL./COLL.	2.6E-09	2.6E-09	2.6E-09	2.6E-09
RUNAWAY ROLLING STOCK	1.3E-09	1.3E-09	1.3E-09	1.3E-09
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	6.6E-07	6.6E-07	6.6E-07	6.6E-07
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**3.6E-06**	**3.6E-06**	**3.6E-06**	**3.6E-06**

Table A-24 Normalized ratio of occurrences with serious injuries and ETC preventability - OCS method of control.

OCS Fatalities	Fa_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	7.9E-07	7.9E-07	7.9E-07	7.9E-07
DERAILMENT INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
DG LEAKER	No Data	No Data	No Data	No Data
EMPLOYEE	1.4E-08	1.4E-08	1.4E-08	1.4E-08
FIRE	No Data	No Data	No Data	No Data
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN DERAILMENT	1.3E-07	1.2E-07	1.2E-07	1.2E-07
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	1.2E-09	1.2E-09	1.2E-09	1.2E-09
R/S COLL. WITH OBJECT	2.7E-09	2.7E-09	2.7E-09	2.7E-09
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	No Data	No Data	No Data	No Data
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	4.2E-07	4.2E-07	4.2E-07	4.2E-07
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**1.3E-06**	**1.3E-06**	**1.3E-06**	**1.3E-06**

Table A-25 Normalized statistical frequency of fatalities per occurrence and ETC preventability - OCS method of control.

CTC

CTC Rolling stock involved	RSi_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	6.4E-07	6.2E-07	6.2E-07	6.2E-07
CREW MEMBER INCAPACITATED	2.2E-08	2.2E-08	2.2E-08	2.2E-08
CROSSING	2.0E-06	2.0E-06	2.0E-06	2.0E-06
DERAILMENT INVOLVING TRACK UNIT	1.8E-07	1.8E-07	1.8E-07	1.8E-07
DG LEAKER	1.2E-06	1.2E-06	1.2E-06	1.2E-06
EMPLOYEE	1.5E-07	1.5E-07	1.5E-07	1.5E-07
FIRE	4.0E-07	4.0E-07	4.0E-07	4.0E-07
MAIN-TRACK SWITCH IN ABNORMAL POSITION	2.3E-08	2.2E-08	4.5E-09	4.5E-09
MAIN-TRACK TRAIN COLLISION	4.3E-07	3.4E-07	3.4E-07	2.9E-07
MAIN-TRACK TRAIN DERAILMENT	6.3E-06	6.2E-06	6.2E-06	6.2E-06
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1.6E-06	9.7E-07	8.8E-07	6.7E-07
R/S COLL. WITH ABANDONED VEHICLE	1.5E-07	1.5E-07	1.5E-07	1.5E-07
R/S COLL. WITH OBJECT	3.5E-07	3.5E-07	3.5E-07	3.5E-07
R/S DAMAGE WITHOUT DERAIL./COLL.	3.5E-07	3.5E-07	3.5E-07	3.5E-07
RUNAWAY ROLLING STOCK	3.5E-07	3.5E-07	3.5E-07	3.5E-07
SIGNAL LESS RESTRICTIVE THAN REQUIRED	2.9E-08	2.9E-08	2.7E-08	1.4E-09
TRESPASSER	1.0E-06	1.0E-06	1.0E-06	1.0E-06
UNPROTECTED OVERLAP OF AUTHORITIES	6.9E-08	6.7E-08	6.7E-08	4.9E-08
Total	**1.5E-05**	**1.4E-05**	**1.4E-05**	**1.4E-05**

Table A-26 Normalized statistical frequency of rolling stock involved per occurrence and ETC preventability - CTC method of control.

CTC Rolling stock derailed	RSd_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	3.5E-08	3.4E-08	3.4E-08	3.4E-08
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	2.5E-07	2.5E-07	2.5E-07	2.5E-07
DERAILMENT INVOLVING TRACK UNIT	1.8E-07	1.8E-07	1.8E-07	1.8E-07
DG LEAKER	1.7E-09	1.7E-09	1.7E-09	1.7E-09
EMPLOYEE	5.1E-09	5.1E-09	5.1E-09	5.1E-09
FIRE	1.5E-09	1.5E-09	1.5E-09	1.5E-09
MAIN-TRACK SWITCH IN ABNORMAL POSITION	2.7E-10	2.6E-10	5.2E-11	5.2E-11
MAIN-TRACK TRAIN COLLISION	2.8E-07	2.2E-07	2.2E-07	1.9E-07
MAIN-TRACK TRAIN DERAILMENT	6.2E-06	6.1E-06	6.0E-06	6.0E-06
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	2.6E-09	1.6E-09	1.4E-09	1.1E-09
R/S COLL. WITH ABANDONED VEHICLE	3.0E-08	3.0E-08	3.0E-08	3.0E-08
R/S COLL. WITH OBJECT	8.3E-08	8.3E-08	8.3E-08	8.3E-08
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	3.6E-08	3.6E-08	3.6E-08	3.6E-08
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	No Data	No Data	No Data	No Data
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**7.1E-06**	**7.0E-06**	**6.9E-06**	**6.8E-06**

Table A-27 Normalized statistical frequency of rolling stock derailed per occurrence and ETC preventability - CTC method of control.

CTC Dangerous goods cars involved	DGCi_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	2.6E-09	2.5E-09	2.5E-09	2.5E-09
CREW MEMBER INCAPACITATED	1.4E-09	1.4E-09	1.4E-09	1.4E-09
CROSSING	1.1E-07	1.1E-07	1.1E-07	1.1E-07
DERAILMENT INVOLVING TRACK UNIT	1.3E-09	1.3E-09	1.3E-09	1.3E-09
DG LEAKER	1.2E-06	1.2E-06	1.2E-06	1.2E-06
EMPLOYEE	1.0E-08	1.0E-08	1.0E-08	1.0E-08
FIRE	9.2E-09	9.2E-09	9.2E-09	9.2E-09
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	2.6E-08	2.1E-08	2.1E-08	1.8E-08
MAIN-TRACK TRAIN DERAILMENT	7.4E-07	7.3E-07	7.3E-07	7.3E-07
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	No Data	No Data	No Data	No Data
R/S COLL. WITH OBJECT	9.0E-09	9.0E-09	8.9E-09	8.9E-09
R/S DAMAGE WITHOUT DERAIL./COLL.	8.3E-08	8.3E-08	8.3E-08	8.3E-08
RUNAWAY ROLLING STOCK	2.8E-08	2.8E-08	2.8E-08	2.8E-08
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	1.4E-09	1.4E-09	1.4E-09	1.4E-09
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**2.2E-06**	**2.2E-06**	**2.2E-06**	**2.2E-06**

Table A-28 Normalized statistical frequency of dangerous goods cars involved per occurrence and ETC preventability - CTC method of control.

CTC Occurrences with serious injuries	Inj_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	4.1E-08	3.9E-08	3.9E-08	3.9E-08
CREW MEMBER INCAPACITATED	2.1E-08	2.1E-08	2.1E-08	2.1E-08
CROSSING	6.4E-07	6.4E-07	6.4E-07	6.4E-07
DERAILMENT INVOLVING TRACK UNIT	4.0E-09	4.0E-09	4.0E-09	4.0E-09
DG LEAKER	1.2E-08	1.2E-08	1.2E-08	1.2E-08
EMPLOYEE	1.3E-07	1.3E-07	1.3E-07	1.3E-07
FIRE	2.1E-08	2.1E-08	2.1E-08	2.1E-08
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	9.2E-09	7.3E-09	7.3E-09	6.3E-09
MAIN-TRACK TRAIN DERAILMENT	1.4E-08	1.3E-08	1.3E-08	1.3E-08
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1.3E-09	7.9E-10	7.2E-10	5.5E-10
R/S COLL. WITH ABANDONED VEHICLE	4.0E-09	4.0E-09	4.0E-09	4.0E-09
R/S COLL. WITH OBJECT	1.4E-08	1.4E-08	1.4E-08	1.4E-08
R/S DAMAGE WITHOUT DERAIL./COLL.	3.3E-09	3.3E-09	3.3E-09	3.3E-09
RUNAWAY ROLLING STOCK	8.5E-10	8.5E-10	8.5E-10	8.5E-10
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	1.0E-06	1.0E-06	1.0E-06	1.0E-06
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**1.9E-06**	**1.9E-06**	**1.9E-06**	**1.9E-06**

Table A-29 Normalized ratio of occurrences with serious injuries and ETC preventability - CTC method of control.

CTC Fatalities	Fa_n per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	2.0E-07	2.0E-07	2.0E-07	2.0E-07
DERAILMENT INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
DG LEAKER	No Data	No Data	No Data	No Data
EMPLOYEE	1.3E-08	1.3E-08	1.3E-08	1.3E-08
FIRE	No Data	No Data	No Data	No Data
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN DERAILMENT	5.4E-08	5.3E-08	5.3E-08	5.3E-08
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	1.3E-09	1.3E-09	1.3E-09	1.3E-09
R/S COLL. WITH OBJECT	1.3E-09	1.3E-09	1.3E-09	1.3E-09
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	No Data	No Data	No Data	No Data
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	6.4E-07	6.4E-07	6.4E-07	6.4E-07
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**9.1E-07**	**9.1E-07**	**9.1E-07**	**9.1E-07**

Table A-30 Normalized statistical frequency of fatalities per occurrence and ETC preventability - CTC method of control.

Estimated Severity Indicators for Selected Subdivisions Based on Normalized Ratios in the Next 10 Years

Kingston subdivision according to class of track

Kingston according to class of track	
Occurrence group	**Expected No. occurrences**
COLLISION INVOLVING TRACK UNIT	5.6
CREW MEMBER INCAPACITATED	0.4
CROSSING	39.2
DERAILMENT INVOLVING TRACK UNIT	3.2
DG LEAKER	23.1
EMPLOYEE	2.5
FIRE	8.2
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.9
MAIN-TRACK TRAIN COLLISION	1.2
MAIN-TRACK TRAIN DERAILMENT	18.1
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	30.8
R/S COLL. WITH ABANDONED VEHICLE	2.9
R/S COLL. WITH OBJECT	5.5
R/S DAMAGE WITHOUT DERAIL./COLL.	5.0
RUNAWAY ROLLING STOCK	2.2
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.5
TRESPASSER	21.1
UNPROTECTED OVERLAP OF AUTHORITIES	1.2
Total	**171.7**

Table A-31 Expected number of occurrences in 10 years according to normalized ratios for the same class of track - Kingston subdivision.

Kingston according to class of track Rolling stock involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	11.6	11.2	11.2	11.2
CREW MEMBER INCAPACITATED	0.4	0.4	0.4	0.4
CROSSING	46.8	46.8	46.8	46.8
DERAILMENT INVOLVING TRACK UNIT	3.4	3.4	3.4	3.4
DG LEAKER	23.1	23.1	23.1	23.1
EMPLOYEE	2.9	2.9	2.9	2.9
FIRE	8.9	8.9	8.9	8.9
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1.0	0.9	0.2	0.2
MAIN-TRACK TRAIN COLLISION	7.3	5.8	5.8	5.0
MAIN-TRACK TRAIN DERAILMENT	114.4	113.1	111.7	111.6
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	32.3	19.5	17.7	13.4
R/S COLL. WITH ABANDONED VEHICLE	3.6	3.6	3.6	3.6
R/S COLL. WITH OBJECT	7.2	7.2	7.2	7.2
R/S DAMAGE WITHOUT DERAIL./COLL.	7.1	7.1	7.1	7.1
RUNAWAY ROLLING STOCK	7.2	7.2	7.2	7.2
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.6	0.6	0.5	0.0
TRESPASSER	21.4	21.4	21.4	21.4
UNPROTECTED OVERLAP OF AUTHORITIES	1.6	1.6	1.6	1.1
Total	**300.6**	**284.6**	**280.7**	**274.6**

Table A-32 Expected number of rolling stock involved in 10 years according to normalized ratios for the same class of track - Kingston subdivision.

Kingston according to class of track Rolling stock derailed	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.6	0.6	0.6	0.6
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	6.0	6.0	6.0	6.0
DERAILMENT INVOLVING TRACK UNIT	3.3	3.3	3.3	3.3
DG LEAKER	0.0	0.0	0.0	0.0
EMPLOYEE	0.1	0.1	0.1	0.1
FIRE	0.0	0.0	0.0	0.0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.0	0.0	0.0	0.0
MAIN-TRACK TRAIN COLLISION	4.7	3.8	3.8	3.2
MAIN-TRACK TRAIN DERAILMENT	111.8	110.6	109.3	109.2
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.1	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.7	0.7	0.7	0.7
R/S COLL. WITH OBJECT	1.7	1.7	1.7	1.7
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	0.7	0.7	0.7	0.7
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	No Data	No Data	No Data	No Data
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**129.9**	**127.6**	**126.3**	**125.7**

Table A-33 Expected number of rolling stock derailed in 10 years according to normalized ratios for the same class of track - Kingston subdivision.

Kingston according to class of track Dangerous goods cars involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
CREW MEMBER INCAPACITATED	0.0	0.0	0.0	0.0
CROSSING	2.6	2.6	2.6	2.6
DERAILMENT INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
DG LEAKER	23.1	23.1	23.1	23.1
EMPLOYEE	0.2	0.2	0.2	0.2
FIRE	0.2	0.2	0.2	0.2
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.4	0.4	0.4	0.3
MAIN-TRACK TRAIN DERAILMENT	13.5	13.3	13.1	13.1
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	No Data	No Data	No Data	No Data
R/S COLL. WITH OBJECT	0.2	0.2	0.2	0.2
R/S DAMAGE WITHOUT DERAIL./COLL.	1.7	1.7	1.7	1.7
RUNAWAY ROLLING STOCK	0.6	0.6	0.6	0.6
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	0.0	0.0	0.0	0.0
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**42.5**	**42.3**	**42.1**	**42.1**

Table A-34 Expected number of dangerous goods cars involved in 10 years according to normalized ratios for the same class of track - Kingston subdivision.

Kingston according to class of track Occurrences with serious injuries	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.7	0.7	0.7	0.7
CREW MEMBER INCAPACITATED	0.4	0.4	0.4	0.4
CROSSING	15.3	15.3	15.3	15.3
DERAILMENT INVOLVING TRACK UNIT	0.1	0.1	0.1	0.1
DG LEAKER	0.2	0.2	0.2	0.2
EMPLOYEE	2.5	2.5	2.5	2.5
FIRE	0.5	0.5	0.5	0.5
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.2	0.1	0.1	0.1
MAIN-TRACK TRAIN DERAILMENT	0.2	0.2	0.2	0.2
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.0	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.1	0.1	0.1	0.1
R/S COLL. WITH OBJECT	0.3	0.3	0.3	0.3
R/S DAMAGE WITHOUT DERAIL./COLL.	0.1	0.1	0.1	0.1
RUNAWAY ROLLING STOCK	0.0	0.0	0.0	0.0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	21.0	21.0	21.0	21.0
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**41.6**	**41.5**	**41.5**	**41.5**

Table A-35 Expected number of occurrences with serious injuries in 10 years according to normalized ratios for the same class of track - Kingston subdivision.

Kingston according to class of track Fatalities	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	4.8	4.8	4.8	4.8
DERAILMENT INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
DG LEAKER	No Data	No Data	No Data	No Data
EMPLOYEE	0.3	0.3	0.3	0.3
FIRE	No Data	No Data	No Data	No Data
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN DERAILMENT	1.0	1.0	1.0	1.0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	0.0	0.0	0.0	0.0
R/S COLL. WITH OBJECT	0.0	0.0	0.0	0.0
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	No Data	No Data	No Data	No Data
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	13.4	13.4	13.4	13.4
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**19.5**	**19.5**	**19.5**	**19.5**

Table A-36 Expected number of fatalities in 10 years according to normalized ratios for the same class of track - Kingston subdivision.

Kingston subdivision according to method of control

Kingston according to method of control	
Occurrence group	**Expected No. occurrences**
COLLISION INVOLVING TRACK UNIT	5.7
CREW MEMBER INCAPACITATED	0.4
CROSSING	30.1
DERAILMENT INVOLVING TRACK UNIT	3.1
DG LEAKER	22.1
EMPLOYEE	2.4
FIRE	6.8
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.4
MAIN-TRACK TRAIN COLLISION	1.3
MAIN-TRACK TRAIN DERAILMENT	18.4
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	28.3
R/S COLL. WITH ABANDONED VEHICLE	2.3
R/S COLL. WITH OBJECT	4.9
R/S DAMAGE WITHOUT DERAIL./COLL.	4.5
RUNAWAY ROLLING STOCK	1.9
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.5
TRESPASSER	18.6
UNPROTECTED OVERLAP OF AUTHORITIES	0.9
Total	**152.7**

Table A-37 Expected number of occurrences in 10 years according to normalized ratios for the same method of control - Kingston subdivision.

Kingston according to method of control Rolling stock involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	11.8	11.4	11.4	11.4
CREW MEMBER INCAPACITATED	0.4	0.4	0.4	0.4
CROSSING	36.0	36.0	36.0	36.0
DERAILMENT INVOLVING TRACK UNIT	3.4	3.4	3.4	3.4
DG LEAKER	22.1	22.1	22.1	22.1
EMPLOYEE	2.7	2.7	2.7	2.7
FIRE	7.4	7.4	7.4	7.4
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.4	0.4	0.1	0.1
MAIN-TRACK TRAIN COLLISION	7.9	6.3	6.3	5.4
MAIN-TRACK TRAIN DERAILMENT	116.1	114.8	113.5	113.4
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	29.6	17.9	16.2	12.3
R/S COLL. WITH ABANDONED VEHICLE	2.8	2.8	2.8	2.8
R/S COLL. WITH OBJECT	6.5	6.5	6.4	6.4
R/S DAMAGE WITHOUT DERAIL./COLL.	6.4	6.4	6.4	6.4
RUNAWAY ROLLING STOCK	6.4	6.4	6.4	6.4
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.5	0.5	0.5	0.0
TRESPASSER	18.8	18.8	18.8	18.8
UNPROTECTED OVERLAP OF AUTHORITIES	1.3	1.2	1.2	0.9
Total	**280.5**	**265.5**	**262.1**	**256.3**

Table A-38 Expected number of rolling stock involved in 10 years according to normalized ratios for the same method of control - Kingston subdivision.

Kingston according to method of control Rolling stock derailed	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.7	0.6	0.6	0.6
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	4.6	4.6	4.6	4.6
DERAILMENT INVOLVING TRACK UNIT	3.3	3.3	3.3	3.3
DG LEAKER	0.0	0.0	0.0	0.0
EMPLOYEE	0.1	0.1	0.1	0.1
FIRE	0.0	0.0	0.0	0.0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.0	0.0	0.0	0.0
MAIN-TRACK TRAIN COLLISION	5.1	4.1	4.1	3.5
MAIN-TRACK TRAIN DERAILMENT	113.6	112.3	111.0	110.9
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.0	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.6	0.6	0.6	0.6
R/S COLL. WITH OBJECT	1.5	1.5	1.5	1.5
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	0.7	0.7	0.7	0.7
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	No Data	No Data	No Data	No Data
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**130.2**	**127.8**	**126.5**	**125.8**

Table A-39 Expected number of rolling stock derailed in 10 years according to normalized ratios for the same method of control - Kingston subdivision.

Kingston according to method of control Dangerous goods cars involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
CREW MEMBER INCAPACITATED	0.0	0.0	0.0	0.0
CROSSING	2.0	2.0	2.0	2.0
DERAILMENT INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
DG LEAKER	22.1	22.1	22.1	22.1
EMPLOYEE	0.2	0.2	0.2	0.2
FIRE	0.2	0.2	0.2	0.2
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.5	0.4	0.4	0.3
MAIN-TRACK TRAIN DERAILMENT	13.7	13.5	13.4	13.3
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	No Data	No Data	No Data	No Data
R/S COLL. WITH OBJECT	0.2	0.2	0.2	0.2
R/S DAMAGE WITHOUT DERAIL./COLL.	1.5	1.5	1.5	1.5
RUNAWAY ROLLING STOCK	0.5	0.5	0.5	0.5
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	0.0	0.0	0.0	0.0
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**40.9**	**40.6**	**40.5**	**40.4**

Table A-40 Expected number of dangerous goods cars involved in 10 years according to normalized ratios for the same method of control - Kingston subdivision.

Kingston according to method of control Occurrences with serious injuries	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.7	0.7	0.7	0.7
CREW MEMBER INCAPACITATED	0.4	0.4	0.4	0.4
CROSSING	11.7	11.7	11.7	11.7
DERAILMENT INVOLVING TRACK UNIT	0.1	0.1	0.1	0.1
DG LEAKER	0.2	0.2	0.2	0.2
EMPLOYEE	2.4	2.4	2.4	2.4
FIRE	0.4	0.4	0.4	0.4
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.2	0.1	0.1	0.1
MAIN-TRACK TRAIN DERAILMENT	0.2	0.2	0.2	0.2
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.0	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.1	0.1	0.1	0.1
R/S COLL. WITH OBJECT	0.3	0.3	0.3	0.3
R/S DAMAGE WITHOUT DERAIL./COLL.	0.1	0.1	0.1	0.1
RUNAWAY ROLLING STOCK	0.0	0.0	0.0	0.0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	18.5	18.5	18.5	18.5
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**35.2**	**35.2**	**35.1**	**35.1**

Table A-41 Expected number of occurrences with serious injuries in 10 years according to normalized ratios for the same method of control - Kingston subdivision.

Kingston according to method of control Fatalities	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	3.7	3.7	3.7	3.7
DERAILMENT INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
DG LEAKER	No Data	No Data	No Data	No Data
EMPLOYEE	0.2	0.2	0.2	0.2
FIRE	No Data	No Data	No Data	No Data
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN DERAILMENT	1.0	1.0	1.0	1.0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	0.0	0.0	0.0	0.0
R/S COLL. WITH OBJECT	0.0	0.0	0.0	0.0
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	No Data	No Data	No Data	No Data
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	11.8	11.8	11.8	11.8
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**16.7**	**16.7**	**16.7**	**16.7**

Table A-42 Expected number of fatalities in 10 years according to normalized ratios for the same method of control - Kingston subdivision.

Windermere subdivision according to class of track

Windermere according to class of track	Expected No. occurrences
Occurrence group	**based on: per year, per train mile**
COLLISION INVOLVING TRACK UNIT	2.0
CREW MEMBER INCAPACITATED	0.2
CROSSING	13.8
DERAILMENT INVOLVING TRACK UNIT	1.1
DG LEAKER	8.1
EMPLOYEE	0.9
FIRE	2.9
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.3
MAIN-TRACK TRAIN COLLISION	0.4
MAIN-TRACK TRAIN DERAILMENT	6.4
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	10.9
R/S COLL. WITH ABANDONED VEHICLE	1.0
R/S COLL. WITH OBJECT	1.9
R/S DAMAGE WITHOUT DERAIL./COLL.	1.8
RUNAWAY ROLLING STOCK	0.8
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.2
TRESPASSER	7.5
UNPROTECTED OVERLAP OF AUTHORITIES	0.4
Total	**60.6**

Table A-43 Expected number of occurrences in 10 years according to normalized ratios for the same class of track - Windermere subdivision.

Windermere according to class of track Rolling stock involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	4.1	4.0	3.9	3.9
CREW MEMBER INCAPACITATED	0.2	0.2	0.2	0.2
CROSSING	16.5	16.5	16.5	16.5
DERAILMENT INVOLVING TRACK UNIT	1.2	1.2	1.2	1.2
DG LEAKER	8.1	8.1	8.1	8.1
EMPLOYEE	1.0	1.0	1.0	1.0
FIRE	3.1	3.1	3.1	3.1
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.3	0.3	0.1	0.1
MAIN-TRACK TRAIN COLLISION	2.6	2.0	2.0	1.8
MAIN-TRACK TRAIN DERAILMENT	40.4	39.9	39.4	39.4
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	11.4	6.9	6.2	4.7
R/S COLL. WITH ABANDONED VEHICLE	1.3	1.3	1.3	1.3
R/S COLL. WITH OBJECT	2.6	2.6	2.5	2.5
R/S DAMAGE WITHOUT DERAIL./COLL.	2.5	2.5	2.5	2.5
RUNAWAY ROLLING STOCK	2.5	2.5	2.5	2.5
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.2	0.2	0.2	0.0
TRESPASSER	7.6	7.6	7.6	7.6
UNPROTECTED OVERLAP OF AUTHORITIES	0.6	0.5	0.5	0.4
Total	**106.1**	**100.4**	**99.1**	**96.9**

Table A-44 Expected number of rolling stock involved in 10 years according to normalized ratios for the same class of track - Windermere subdivision.

Windermere according to class of track Rolling stock derailed	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.2	0.2	0.2	0.2
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	2.1	2.1	2.1	2.1
DERAILMENT INVOLVING TRACK UNIT	1.2	1.2	1.2	1.2
DG LEAKER	0.0	0.0	0.0	0.0
EMPLOYEE	0.0	0.0	0.0	0.0
FIRE	0.0	0.0	0.0	0.0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.0	0.0	0.0	0.0
MAIN-TRACK TRAIN COLLISION	1.7	1.3	1.3	1.1
MAIN-TRACK TRAIN DERAILMENT	39.5	39.0	38.6	38.5
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.0	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.3	0.3	0.3	0.3
R/S COLL. WITH OBJECT	0.6	0.6	0.6	0.6
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	0.3	0.3	0.3	0.3
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	No Data	No Data	No Data	No Data
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**45.8**	**45.0**	**44.6**	**44.4**

Table A-45 Expected number of rolling stock derailed in 10 years according to normalized ratios for the same class of track - Windermere subdivision.

Windermere according to class of track Dangerous goods cars involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
CREW MEMBER INCAPACITATED	0.0	0.0	0.0	0.0
CROSSING	0.9	0.9	0.9	0.9
DERAILMENT INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
DG LEAKER	8.1	8.1	8.1	8.1
EMPLOYEE	0.1	0.1	0.1	0.1
FIRE	0.1	0.1	0.1	0.1
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.2	0.1	0.1	0.1
MAIN-TRACK TRAIN DERAILMENT	4.7	4.7	4.6	4.6
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	No Data	No Data	No Data	No Data
R/S COLL. WITH OBJECT	0.1	0.1	0.1	0.1
R/S DAMAGE WITHOUT DERAIL./COLL.	0.6	0.6	0.6	0.6
RUNAWAY ROLLING STOCK	0.2	0.2	0.2	0.2
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	0.0	0.0	0.0	0.0
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**15.0**	**14.9**	**14.9**	**14.8**

Table A-46 Expected number of dangerous goods cars involved in 10 years according to normalized ratios for the same class of track - Windermere subdivision.

Windermere according to class of track Occurrences with serious injuries	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.3	0.3	0.3	0.3
CREW MEMBER INCAPACITATED	0.1	0.1	0.1	0.1
CROSSING	5.4	5.4	5.4	5.4
DERAILMENT INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
DG LEAKER	0.1	0.1	0.1	0.1
EMPLOYEE	0.9	0.9	0.9	0.9
FIRE	0.2	0.2	0.2	0.2
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.1	0.0	0.0	0.0
MAIN-TRACK TRAIN DERAILMENT	0.1	0.1	0.1	0.1
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.0	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.0	0.0	0.0	0.0
R/S COLL. WITH OBJECT	0.1	0.1	0.1	0.1
R/S DAMAGE WITHOUT DERAIL./COLL.	0.0	0.0	0.0	0.0
RUNAWAY ROLLING STOCK	0.0	0.0	0.0	0.0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	7.4	7.4	7.4	7.4
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**14.7**	**14.7**	**14.7**	**14.6**

Table A-47 Expected number of occurrences with serious injuries in 10 years according to normalized ratios for the same class of track - Windermere subdivision.

Windermere according to class of track Fatalities	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	1.7	1.7	1.7	1.7
DERAILMENT INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
DG LEAKER	No Data	No Data	No Data	No Data
EMPLOYEE	0.1	0.1	0.1	0.1
FIRE	No Data	No Data	No Data	No Data
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN DERAILMENT	0.3	0.3	0.3	0.3
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	0.0	0.0	0.0	0.0
R/S COLL. WITH OBJECT	0.0	0.0	0.0	0.0
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	No Data	No Data	No Data	No Data
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	4.7	4.7	4.7	4.7
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**6.9**	**6.9**	**6.9**	**6.9**

Table A-48 Expected number of fatalities in 10 years according to normalized ratios for the same class of track - Windermere subdivision.

Windermere subdivision according to method of control

Windermere according to method of control	
Occurrence group	**Occurrences per year, per train mile**
COLLISION INVOLVING TRACK UNIT	4.1
CREW MEMBER INCAPACITATED	0.4
CROSSING	41.9
DERAILMENT INVOLVING TRACK UNIT	1.6
DG LEAKER	7.1
EMPLOYEE	0.9
FIRE	3.0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	3.7
MAIN-TRACK TRAIN COLLISION	0.9
MAIN-TRACK TRAIN DERAILMENT	15.1
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	22.6
R/S COLL. WITH ABANDONED VEHICLE	0.7
R/S COLL. WITH OBJECT	3.7
R/S DAMAGE WITHOUT DERAIL./COLL.	1.2
RUNAWAY ROLLING STOCK	1.1
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.0
TRESPASSER	4.3
UNPROTECTED OVERLAP OF AUTHORITIES	2.1
Total	**114.6**

Table A-49 Expected number of occurrences in 10 years according to normalized ratios for the same method of control - Windermere subdivision.

Windermere according to method of control Rolling stock involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	8.5	8.3	8.2	8.2
CREW MEMBER INCAPACITATED	0.4	0.4	0.4	0.4
CROSSING	50.0	50.0	50.0	50.0
DERAILMENT INVOLVING TRACK UNIT	1.7	1.7	1.7	1.7
DG LEAKER	7.1	7.1	7.1	7.1
EMPLOYEE	1.0	1.0	1.0	1.0
FIRE	3.3	3.3	3.3	3.3
MAIN-TRACK SWITCH IN ABNORMAL POSITION	3.9	3.7	0.8	0.8
MAIN-TRACK TRAIN COLLISION	5.4	4.3	4.3	3.7
MAIN-TRACK TRAIN DERAILMENT	95.5	94.4	93.3	93.2
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	23.7	14.3	13.0	9.9
R/S COLL. WITH ABANDONED VEHICLE	0.9	0.9	0.9	0.9
R/S COLL. WITH OBJECT	4.9	4.9	4.9	4.9
R/S DAMAGE WITHOUT DERAIL./COLL.	1.8	1.8	1.8	1.8
RUNAWAY ROLLING STOCK	3.6	3.6	3.6	3.6
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.0	0.0	0.0	0.0
TRESPASSER	4.3	4.3	4.3	4.3
UNPROTECTED OVERLAP OF AUTHORITIES	2.9	2.8	2.8	2.0
Total	**218.8**	**206.7**	**201.3**	**196.7**

Table A-50 Expected number of rolling stock involved in 10 years according to normalized ratios for the same method of control - Windermere subdivision.

Windermere according to method of control Rolling stock derailed	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.5	0.5	0.5	0.5
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	6.4	6.4	6.4	6.4
DERAILMENT INVOLVING TRACK UNIT	1.7	1.7	1.7	1.7
DG LEAKER	0.0	0.0	0.0	0.0
EMPLOYEE	0.0	0.0	0.0	0.0
FIRE	0.0	0.0	0.0	0.0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.0	0.0	0.0	0.0
MAIN-TRACK TRAIN COLLISION	3.5	2.8	2.8	2.4
MAIN-TRACK TRAIN DERAILMENT	93.4	92.3	91.2	91.1
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.0	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.2	0.2	0.2	0.2
R/S COLL. WITH OBJECT	1.2	1.2	1.2	1.2
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	0.4	0.4	0.4	0.4
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	No Data	No Data	No Data	No Data
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**107.2**	**105.4**	**104.3**	**103.8**

Table A-51 Expected number of rolling stock derailed in 10 years according to normalized ratios for the same method of control - Windermere subdivision.

Windermere according to method of control Dangerous goods cars involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
CREW MEMBER INCAPACITATED	0.0	0.0	0.0	0.0
CROSSING	2.8	2.8	2.8	2.8
DERAILMENT INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
DG LEAKER	7.1	7.1	7.1	7.1
EMPLOYEE	0.1	0.1	0.1	0.1
FIRE	0.1	0.1	0.1	0.1
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.3	0.3	0.3	0.2
MAIN-TRACK TRAIN DERAILMENT	11.2	11.1	11.0	11.0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	No Data	No Data	No Data	No Data
R/S COLL. WITH OBJECT	0.1	0.1	0.1	0.1
R/S DAMAGE WITHOUT DERAIL./COLL.	0.4	0.4	0.4	0.4
RUNAWAY ROLLING STOCK	0.3	0.3	0.3	0.3
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	0.0	0.0	0.0	0.0
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**22.5**	**22.3**	**22.2**	**22.1**

Table A-52 Expected number of dangerous goods cars involved in 10 years according to normalized ratios for the same method of control - Windermere subdivision.

Windermere according to method of control Occurrences with serious injuries	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.5	0.5	0.5	0.5
CREW MEMBER INCAPACITATED	0.3	0.3	0.3	0.3
CROSSING	16.3	16.3	16.3	16.3
DERAILMENT INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
DG LEAKER	0.1	0.1	0.1	0.1
EMPLOYEE	0.9	0.9	0.9	0.9
FIRE	0.2	0.2	0.2	0.2
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.1	0.1	0.1	0.1
MAIN-TRACK TRAIN DERAILMENT	0.2	0.2	0.2	0.2
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.0	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.0	0.0	0.0	0.0
R/S COLL. WITH OBJECT	0.2	0.2	0.2	0.2
R/S DAMAGE WITHOUT DERAIL./COLL.	0.0	0.0	0.0	0.0
RUNAWAY ROLLING STOCK	0.0	0.0	0.0	0.0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	4.3	4.3	4.3	4.3
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**23.2**	**23.1**	**23.1**	**23.1**

Table A-53 Expected number of occurrences with serious injuries in 10 years according to normalized ratios for the same method of control - Windermere subdivision.

Windermere according to method of control Fatalities	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	5.1	5.1	5.1	5.1
DERAILMENT INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
DG LEAKER	No Data	No Data	No Data	No Data
EMPLOYEE	0.1	0.1	0.1	0.1
FIRE	No Data	No Data	No Data	No Data
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN DERAILMENT	0.8	0.8	0.8	0.8
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	0.0	0.0	0.0	0.0
R/S COLL. WITH OBJECT	0.0	0.0	0.0	0.0
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	No Data	No Data	No Data	No Data
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	2.7	2.7	2.7	2.7
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**8.8**	**8.7**	**8.7**	**8.7**

Table A-54 Expected number of fatalities in 10 years according to normalized ratios for the same method of control - Windermere subdivision.

Wynyard subdivision according to class of track

Wynyard according to class of track	Expected No. occurrences
Occurrence group	**based on: per year, per train mile**
COLLISION INVOLVING TRACK UNIT	0.9
CREW MEMBER INCAPACITATED	0.0
CROSSING	4.7
DERAILMENT INVOLVING TRACK UNIT	0.4
DG LEAKER	1.4
EMPLOYEE	0.1
FIRE	0.6
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.4
MAIN-TRACK TRAIN COLLISION	0.2
MAIN-TRACK TRAIN DERAILMENT	3.3
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	4.1
R/S COLL. WITH ABANDONED VEHICLE	0.1
R/S COLL. WITH OBJECT	0.7
R/S DAMAGE WITHOUT DERAIL./COLL.	0.2
RUNAWAY ROLLING STOCK	0.2
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.0
TRESPASSER	1.0
UNPROTECTED OVERLAP OF AUTHORITIES	0.3
Total	**18.7**

Table A-55 Expected number of occurrences in 10 years according to normalized ratios for the same class of track - Wynyard subdivision.

Wynyard according to class of track Rolling stock involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	2.0	1.9	1.9	1.9
CREW MEMBER INCAPACITATED	0.0	0.0	0.0	0.0
CROSSING	5.6	5.6	5.6	5.6
DERAILMENT INVOLVING TRACK UNIT	0.4	0.4	0.4	0.4
DG LEAKER	1.4	1.4	1.4	1.4
EMPLOYEE	0.2	0.2	0.2	0.2
FIRE	0.6	0.6	0.6	0.6
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.4	0.4	0.1	0.1
MAIN-TRACK TRAIN COLLISION	1.2	1.0	1.0	0.8
MAIN-TRACK TRAIN DERAILMENT	21.0	20.8	20.5	20.5
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	4.3	2.6	2.4	1.8
R/S COLL. WITH ABANDONED VEHICLE	0.1	0.1	0.1	0.1
R/S COLL. WITH OBJECT	0.9	0.9	0.9	0.9
R/S DAMAGE WITHOUT DERAIL./COLL.	0.3	0.3	0.3	0.3
RUNAWAY ROLLING STOCK	0.7	0.7	0.7	0.7
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.0	0.0	0.0	0.0
TRESPASSER	1.0	1.0	1.0	1.0
UNPROTECTED OVERLAP OF AUTHORITIES	0.5	0.4	0.4	0.3
Total	**40.6**	**38.4**	**37.5**	**36.6**

Table A-56 Expected number of rolling stock involved in 10 years according to normalized ratios for the same class of track - Wynyard subdivision.

Wynyard according to class of track Rolling stock derailed	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.1	0.1	0.1	0.1
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	0.7	0.7	0.7	0.7
DERAILMENT INVOLVING TRACK UNIT	0.4	0.4	0.4	0.4
DG LEAKER	0.0	0.0	0.0	0.0
EMPLOYEE	0.0	0.0	0.0	0.0
FIRE	0.0	0.0	0.0	0.0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.0	0.0	0.0	0.0
MAIN-TRACK TRAIN COLLISION	0.8	0.6	0.6	0.5
MAIN-TRACK TRAIN DERAILMENT	20.6	20.3	20.1	20.1
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.0	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.0	0.0	0.0	0.0
R/S COLL. WITH OBJECT	0.2	0.2	0.2	0.2
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	0.1	0.1	0.1	0.1
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	No Data	No Data	No Data	No Data
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**22.9**	**22.5**	**22.3**	**22.2**

Table A-57 Expected number of rolling stock derailed in 10 years according to normalized ratios for the same class of track - Wynyard subdivision.

Wynyard according to class of track Dangerous goods cars involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
CREW MEMBER INCAPACITATED	0.0	0.0	0.0	0.0
CROSSING	0.3	0.3	0.3	0.3
DERAILMENT INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
DG LEAKER	1.4	1.4	1.4	1.4
EMPLOYEE	0.0	0.0	0.0	0.0
FIRE	0.0	0.0	0.0	0.0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.1	0.1	0.1	0.1
MAIN-TRACK TRAIN DERAILMENT	2.5	2.4	2.4	2.4
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	No Data	No Data	No Data	No Data
R/S COLL. WITH OBJECT	0.0	0.0	0.0	0.0
R/S DAMAGE WITHOUT DERAIL./COLL.	0.1	0.1	0.1	0.1
RUNAWAY ROLLING STOCK	0.1	0.1	0.1	0.1
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	0.0	0.0	0.0	0.0
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**4.5**	**4.4**	**4.4**	**4.4**

Table A-58 Expected number of dangerous goods cars involved in 10 years according to normalized ratios for the same class of track - Wynyard subdivision.

Wynyard according to class of track Occurrences with serious injuries	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.1	0.1	0.1	0.1
CREW MEMBER INCAPACITATED	0.0	0.0	0.0	0.0
CROSSING	1.8	1.8	1.8	1.8
DERAILMENT INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
DG LEAKER	0.0	0.0	0.0	0.0
EMPLOYEE	0.1	0.1	0.1	0.1
FIRE	0.0	0.0	0.0	0.0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.0	0.0	0.0	0.0
MAIN-TRACK TRAIN DERAILMENT	0.0	0.0	0.0	0.0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.0	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.0	0.0	0.0	0.0
R/S COLL. WITH OBJECT	0.0	0.0	0.0	0.0
R/S DAMAGE WITHOUT DERAIL./COLL.	0.0	0.0	0.0	0.0
RUNAWAY ROLLING STOCK	0.0	0.0	0.0	0.0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	1.0	1.0	1.0	1.0
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**3.3**	**3.2**	**3.2**	**3.2**

Table A-59 Expected number of occurrences with serious injuries in 10 years according to normalized ratios for the same class of track - Wynyard subdivision.

Wynyard according to class of track Fatalities	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	0.6	0.6	0.6	0.6
DERAILMENT INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
DG LEAKER	No Data	No Data	No Data	No Data
EMPLOYEE	0.0	0.0	0.0	0.0
FIRE	No Data	No Data	No Data	No Data
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN DERAILMENT	0.2	0.2	0.2	0.2
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	0.0	0.0	0.0	0.0
R/S COLL. WITH OBJECT	0.0	0.0	0.0	0.0
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	No Data	No Data	No Data	No Data
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	0.6	0.6	0.6	0.6
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**1.4**	**1.4**	**1.4**	**1.4**

Table 1 Expected number of fatalities in 10 years according to normalized ratios for the same class of track - Wynyard subdivision.

Wynyard subdivision according to method of control

Wynyard according to method of control	
Occurrence group	**Occurrences per year, per train mile**
COLLISION INVOLVING TRACK UNIT	1.2
CREW MEMBER INCAPACITATED	0.1
CROSSING	12.1
DERAILMENT INVOLVING TRACK UNIT	0.5
DG LEAKER	2.1
EMPLOYEE	0.3
FIRE	0.9
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1.1
MAIN-TRACK TRAIN COLLISION	0.3
MAIN-TRACK TRAIN DERAILMENT	4.4
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	6.6
R/S COLL. WITH ABANDONED VEHICLE	0.2
R/S COLL. WITH OBJECT	1.1
R/S DAMAGE WITHOUT DERAIL./COLL.	0.4
RUNAWAY ROLLING STOCK	0.3
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.0
TRESPASSER	1.2
UNPROTECTED OVERLAP OF AUTHORITIES	0.6
Total	**33.2**

Table A-61 Expected number of occurrences in 10 years according to normalized ratios for the same method of control - Wynyard subdivision.

Wynyard according to method of control Rolling stock involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	2.5	2.4	2.4	2.4
CREW MEMBER INCAPACITATED	0.1	0.1	0.1	0.1
CROSSING	14.5	14.5	14.5	14.5
DERAILMENT INVOLVING TRACK UNIT	0.5	0.5	0.5	0.5
DG LEAKER	2.1	2.1	2.1	2.1
EMPLOYEE	0.3	0.3	0.3	0.3
FIRE	1.0	1.0	1.0	1.0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1.1	1.1	0.2	0.2
MAIN-TRACK TRAIN COLLISION	1.6	1.2	1.2	1.1
MAIN-TRACK TRAIN DERAILMENT	27.6	27.3	27.0	27.0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	6.9	4.1	3.8	2.9
R/S COLL. WITH ABANDONED VEHICLE	0.3	0.3	0.3	0.3
R/S COLL. WITH OBJECT	1.4	1.4	1.4	1.4
R/S DAMAGE WITHOUT DERAIL./COLL.	0.5	0.5	0.5	0.5
RUNAWAY ROLLING STOCK	1.0	1.0	1.0	1.0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0.0	0.0	0.0	0.0
TRESPASSER	1.3	1.3	1.3	1.3
UNPROTECTED OVERLAP OF AUTHORITIES	0.8	0.8	0.8	0.6
Total	**63.4**	**59.8**	**58.3**	**56.9**

Table A-62 Expected number of rolling stock involved in 10 years according to normalized ratios for the same method of control - Wynyard subdivision.

Wynyard according to method of control Rolling stock derailed	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.1	0.1	0.1	0.1
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	1.8	1.8	1.8	1.8
DERAILMENT INVOLVING TRACK UNIT	0.5	0.5	0.5	0.5
DG LEAKER	0.0	0.0	0.0	0.0
EMPLOYEE	0.0	0.0	0.0	0.0
FIRE	0.0	0.0	0.0	0.0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0.0	0.0	0.0	0.0
MAIN-TRACK TRAIN COLLISION	1.0	0.8	0.8	0.7
MAIN-TRACK TRAIN DERAILMENT	27.0	26.7	26.4	26.4
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.0	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.1	0.1	0.1	0.1
R/S COLL. WITH OBJECT	0.3	0.3	0.3	0.3
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	0.1	0.1	0.1	0.1
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	No Data	No Data	No Data	No Data
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**31.0**	**30.5**	**30.2**	**30.1**

Table A-63 Expected number of rolling stock derailed in 10 years according to normalized ratios for the same method of control - Wynyard subdivision.

Wynyard according to method of control Dangerous goods cars involved	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
CREW MEMBER INCAPACITATED	0.0	0.0	0.0	0.0
CROSSING	0.8	0.8	0.8	0.8
DERAILMENT INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
DG LEAKER	2.1	2.1	2.1	2.1
EMPLOYEE	0.0	0.0	0.0	0.0
FIRE	0.0	0.0	0.0	0.0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.1	0.1	0.1	0.1
MAIN-TRACK TRAIN DERAILMENT	3.3	3.2	3.2	3.2
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	No Data	No Data	No Data	No Data
R/S COLL. WITH OBJECT	0.0	0.0	0.0	0.0
R/S DAMAGE WITHOUT DERAIL./COLL.	0.1	0.1	0.1	0.1
RUNAWAY ROLLING STOCK	0.1	0.1	0.1	0.1
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	0.0	0.0	0.0	0.0
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**6.5**	**6.5**	**6.4**	**6.4**

Table A-64 Expected number of dangerous goods cars involved in 10 years according to normalized ratios for the same method of control - Wynyard subdivision.

Wynyard according to method of control Occurrences with serious injuries	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0.2	0.2	0.2	0.2
CREW MEMBER INCAPACITATED	0.1	0.1	0.1	0.1
CROSSING	4.7	4.7	4.7	4.7
DERAILMENT INVOLVING TRACK UNIT	0.0	0.0	0.0	0.0
DG LEAKER	0.0	0.0	0.0	0.0
EMPLOYEE	0.3	0.3	0.3	0.3
FIRE	0.1	0.1	0.1	0.1
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	0.0	0.0	0.0	0.0
MAIN-TRACK TRAIN DERAILMENT	0.1	0.1	0.1	0.1
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0.0	0.0	0.0	0.0
R/S COLL. WITH ABANDONED VEHICLE	0.0	0.0	0.0	0.0
R/S COLL. WITH OBJECT	0.1	0.1	0.1	0.1
R/S DAMAGE WITHOUT DERAIL./COLL.	0.0	0.0	0.0	0.0
RUNAWAY ROLLING STOCK	0.0	0.0	0.0	0.0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	1.2	1.2	1.2	1.2
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**6.7**	**6.7**	**6.7**	**6.7**

Table A-65 Expected number of occurrences with serious injuries in 10 years according to normalized ratios for the same method of control - Wynyard subdivision.

Wynyard according to method of control Fatalities	per year, per train mile			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
CREW MEMBER INCAPACITATED	No Data	No Data	No Data	No Data
CROSSING	1.5	1.5	1.5	1.5
DERAILMENT INVOLVING TRACK UNIT	No Data	No Data	No Data	No Data
DG LEAKER	No Data	No Data	No Data	No Data
EMPLOYEE	0.0	0.0	0.0	0.0
FIRE	No Data	No Data	No Data	No Data
MAIN-TRACK SWITCH IN ABNORMAL POSITION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN COLLISION	No Data	No Data	No Data	No Data
MAIN-TRACK TRAIN DERAILMENT	0.2	0.2	0.2	0.2
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	No Data	No Data	No Data	No Data
R/S COLL. WITH ABANDONED VEHICLE	0.0	0.0	0.0	0.0
R/S COLL. WITH OBJECT	0.0	0.0	0.0	0.0
R/S DAMAGE WITHOUT DERAIL./COLL.	No Data	No Data	No Data	No Data
RUNAWAY ROLLING STOCK	No Data	No Data	No Data	No Data
SIGNAL LESS RESTRICTIVE THAN REQUIRED	No Data	No Data	No Data	No Data
TRESPASSER	0.8	0.8	0.8	0.8
UNPROTECTED OVERLAP OF AUTHORITIES	No Data	No Data	No Data	No Data
Total	**2.5**	**2.5**	**2.5**	**2.5**

Table A-66 Expected number of fatalities in 10 years according to normalized ratios for the same method of control - Wynyard subdivision.

Analysis of Occurrences Within Selected Subdivisions

Kingston subdivision

Severity indicators - factual and ETC preventable

Subdivision	KINGSTON					
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**Cccurrence with serious injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	5	12	1	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING	36	37	2	1	17	8
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0	0	0
DG LEAKER	7	7	0	7	0	0
EMPLOYEE	3	3	0	0	3	1
FIRE	9	9	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	0	0	0	0
MAIN-TRACK TRAIN COLLISION	6	44	24	6	0	0
MAIN-TRACK TRAIN DERAILMENT	21	192	171	43	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	37	40	0	0	1	0
R/S COLL. WITH ABANDONED VEHICLE	1	1	0	0	0	0
R/S COLL. WITH OBJECT	12	20	0	0	1	0
R/S DAMAGE WITHOUT	10	17	0	2	0	0
DERAIL./COLL. RUNAWAY ROLLING STOCK	2	7	0	0	1	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	2	2	0	0	0	0
TRESPASSER UNPROTECTED	56	56	0	0	56	47
OVERLAP OF AUTHORITIES	0	0	0	0	0	0
Grand Total	**208**	**448**	**198**	**59**	**79**	**56**

Table A-67 Severity indicators (2007 - 2016) at the Kingston subdivision.

Subdivision	KINGSTON		ETC L 1 1			
			Preventability			
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**Occurrence with serious injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	2	4	1	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING	0	0	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0	0	0
DG LEAKER	0	0	0	0	0	0
EMPLOYEE	0	0	0	0	0	0
FIRE	0	0	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	21	24	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0	0	0
TRESPASSER	0	0	0	0	0	0
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0	0	0
Grand Total	**23**	**28**	**1**	**0**	**0**	**0**

Table A-68 Severity indicators (2007 - 2016) that could have been prevented by ETC L1 at the Kingston subdivision.

Subdivision	KINGSTON		ETC L 3	1		
			Preventability			
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**Occurrence with serious injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	2	4	1	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING	0	0	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0	0	0
DG LEAKER	0	0	0	0	0	0
EMPLOYEE	0	0	0	0	0	0
FIRE	0	0	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	21	24	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0	0	0
TRESPASSER UNPROTECTED	0	0	0	0	0	0
OVERLAP OF AUTHORITIES	0	0	0	0	0	0
Grand Total	**23**	**28**	**1**	**0**	**0**	**0**

Table A-69 Severity indicators (2007 - 2016) that could have been prevented by ETC L3 at the Kingston subdivision.

Subdivision	KINGSTON		ETC L 4	1		
			Preventability			
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**Occurrence with serious injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	2	4	1	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING	0	0	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0	0	0
DG LEAKER	0	0	0	0	0	0
EMPLOYEE	0	0	0	0	0	0
FIRE	0	0	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	27	30	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	2	2	0	0	0	0
TRESPASSER	0	0	0	0	0	0
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0	0	0
Grand Total	**31**	**36**	**1**	**0**	**0**	**0**

Table A-70 Severity indicators (2007 - 2016) that could have been prevented by ETC L4 at the Kingston subdivision.

Severity indicators - factual and reduction if ETC implemented

KINGSTON	No. Occurrences			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	5	3	3	3
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	36	36	36	36
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	7	7	7	7
EMPLOYEE	3	3	3	3
FIRE	9	9	9	9
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	1	1
MAIN-TRACK TRAIN COLLISION	6	6	6	6
MAIN-TRACK TRAIN DERAILMENT	21	21	21	21
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	37	16	16	10
R/S COLL. WITH ABANDONED VEHICLE	1	1	1	1
R/S COLL. WITH OBJECT	12	12	12	12
R/S DAMAGE WITHOUT DERAIL./COLL.	10	10	10	10
RUNAWAY ROLLING STOCK	2	2	2	2
SIGNAL LESS RESTRICTIVE THAN REQUIRED	2	2	2	0
TRESPASSER	56	56	56	56
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**208**	**185**	**185**	**177**

Table A-71 No. occurrences (2007 - 2016) and its reduction if ETC had been implemented at the Kingston subdivision.

KINGSTON	No. rolling stock involved			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	12	8	8	8
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	37	37	37	37
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	7	7	7	7
EMPLOYEE	3	3	3	3
FIRE	9	9	9	9
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	1	1
MAIN-TRACK TRAIN COLLISION	44	44	44	44
MAIN-TRACK TRAIN DERAILMENT	192	192	192	192
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	40	16	16	10
R/S COLL. WITH ABANDONED VEHICLE	1	1	1	1
R/S COLL. WITH OBJECT	20	20	20	20
R/S DAMAGE WITHOUT DERAIL./COLL.	17	17	17	17
RUNAWAY ROLLING STOCK	7	7	7	7
SIGNAL LESS RESTRICTIVE THAN REQUIRED	2	2	2	0
TRESPASSER	56	56	56	56
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**448**	**420**	**420**	**412**

Table A-72 No. rolling stock involved (2007 - 2016) and its reduction if ETC had been implemented at the Kingston subdivision.

KINGSTON	No. rolling stock derailed			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	1	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	2	2	2	2
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	0	0	0	0
EMPLOYEE	0	0	0	0
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	24	24	24	24
MAIN-TRACK TRAIN DERAILMENT	171	171	171	171
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	0	0	0	0
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**198**	**197**	**197**	**197**

Table A-73 No. rolling stock derailed (2007 - 2016) and its reduction if ETC had been implemented at the Kingston subdivision.

KINGSTON	No. dangerous goods cars involved			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	1	1	1	1
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	7	7	7	7
EMPLOYEE	0	0	0	0
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	6	6	6	6
MAIN-TRACK TRAIN DERAILMENT	43	43	43	43
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	2	2	2	2
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	0	0	0	0
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**59**	**59**	**59**	**59**

Table A-74 No. dangerous goods cars involved (2007 - 2016) and its reduction if ETC had been implemented at the Kingston subdivision.

KINGSTON	No. occurrences with serious injuries			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	17	17	17	17
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	0	0	0	0
EMPLOYEE	3	3	3	3
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1	1	1	1
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	1	1	1	1
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	1	1	1	1
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	56	56	56	56
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**79**	**79**	**79**	**79**

Table A-75 No. occurrences with serious injuries (2007 - 2016) and its reduction if ETC had been implemented at the Kingston subdivision.

KINGSTON	No. fatalities			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	8	8	8	8
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	0	0	0	0
EMPLOYEE	1	1	1	1
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	47	47	47	47
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**56**	**56**	**56**	**56**

Table A-76 No. fatalities (2007 - 2016) and its reduction if ETC had been implemented at the Kingston subdivision.

Windermere subdivision

Severity indicators - factual and ETC preventable

Subdivision	WINDERMERE					
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**Occurrence with serious injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	1	2	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING	5	5	0	0	3	1
DERAILMENT INVOLVING TRACK UNIT	2	2	2	0	0	0
DG LEAKER	2	2	0	2	0	0
EMPLOYEE	1	1	0	0	1	0
FIRE	0	0	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	6	27	24	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	13	13	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	1	1	0	0	0	0
R/S COLL. WITH OBJECT	5	5	1	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0	0	0
TRESPASSER	1	1	0	0	1	1
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0	0	0
Grand Total	**38**	**60**	**27**	**2**	**5**	**2**

Table A-77 Severity indicators (2007 - 2016) at the Windermere subdivision.

Subdivision	WINDERMERE		ETC L 1	1		
			Preventability			
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**Occurrence with serious injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	0	0	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING	0	0	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0	0	0
DG LEAKER	0	0	0	0	0	0
EMPLOYEE	0	0	0	0	0	0
FIRE	0	0	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	3	3	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0	0	0
TRESPASSER	0	0	0	0	0	0
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0	0	0
Grand Total	**3**	**3**	**0**	**0**	**0**	**0**

Table A-78 Severity indicators (2007 - 2016) that could have been prevented by ETC L1 at the Windermere subdivision.

Subdivision	WINDERMERE		ETC L 3	1		
			Preventability			
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**Occurrence with serious injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	0	0	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING	0	0	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0	0	0
DG LEAKER	0	0	0	0	0	0
EMPLOYEE	0	0	0	0	0	0
FIRE	0	0	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	4	4	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0	0	0
TRESPASSER	0	0	0	0	0	0
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0	0	0
Grand Total	**5**	**5**	**0**	**0**	**0**	**0**

Table A-79 Severity indicators (2007 - 2016) that could have been prevented by ETC L3 at the Windermere subdivision.

Subdivision	WINDERMERE		ETC L 4	1		
			Preventability			
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**occurrence with serious Injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	0	0	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING	0	0	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0	0	0
DG LEAKER	0	0	0	0	0	0
EMPLOYEE	0	0	0	0	0	0
FIRE	0	0	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	10	10	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0	0	0
TRESPASSER UNPROTECTED	0	0	0	0	0	0
OVERLAP OF AUTHORITIES	0	0	0	0	0	0
Grand Total	**11**	**11**	**0**	**0**	**0**	**0**

Table A-80 Severity indicators (2007 - 2016) that could have been prevented by ETC L4 at the Windermere subdivision.

Severity indicators - factual and potential reduction if ETC implemented

WINDERMERE	No. Occurrences			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	1	1	1	1
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	5	5	5	5
DERAILMENT INVOLVING TRACK UNIT	2	2	2	2
DG LEAKER	2	2	2	2
EMPLOYEE	1	1	1	1
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	6	6	6	6
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	13	10	9	3
R/S COLL. WITH ABANDONED VEHICLE	1	1	1	1
R/S COLL. WITH OBJECT	5	5	5	5
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	1	1	1	1
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**38**	**35**	**33**	**27**

Table A-81 No. occurrences (2007 - 2016) and its reduction if ETC had been implemented at the Windermere subdivision.

WINDERMERE	No. rolling stock involved			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	2	2	2	2
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	5	5	5	5
DERAILMENT INVOLVING TRACK UNIT	2	2	2	2
DG LEAKER	2	2	2	2
EMPLOYEE	1	1	1	1
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	27	27	27	27
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	13	10	9	3
R/S COLL. WITH ABANDONED VEHICLE	1	1	1	1
R/S COLL. WITH OBJECT	5	5	5	5
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	1	1	1	1
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**60**	**57**	**55**	**49**

Table A-82 No. rolling stock involved (2007 - 2016) and its reduction if ETC had been implemented at the Windermere subdivision.

WINDERMERE	No. rolling stock derailed			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	2	2	2	2
DG LEAKER	0	0	0	0
EMPLOYEE	0	0	0	0
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	24	24	24	24
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	1	1	1	1
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	0	0	0	0
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**27**	**27**	**27**	**27**

Table A-83 No. rolling stock derailed (2007 - 2016) and its reduction if ETC had been implemented at the Windermere subdivision.

WINDERMERE	No. dangerous goods cars involved			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	2	2	2	2
EMPLOYEE	0	0	0	0
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	0	0	0	0
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**2**	**2**	**2**	**2**

Table A-84 No. dangerous goods cars involved (2007 - 2016) and its reduction if ETC had been implemented at the Windermere subdivision.

WINDERMERE	No. occurrences with serious injuries			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	3	3	3	3
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	0	0	0	0
EMPLOYEE	1	1	1	1
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	1	1	1	1
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**5**	**5**	**5**	**5**

Table A-85 No. occurrences with serious injuries (2007 - 2016) and its reduction if ETC had been implemented at the Windermere subdivision.

WINDERMERE	No. fatalities			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	1	1	1	1
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	0	0	0	0
EMPLOYEE	0	0	0	0
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	1	1	1	1
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**2**	**2**	**2**	**2**

Table A-86 No. fatalities (2007 - 2016) and its reduction if ETC had been implemented at the Windermere subdivision.

Wynyard subdivision

Severity indicators - factual and ETC preventable

Subdivision	WYNYARD					
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**Occurrence with serious injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	0	0	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING DERAILMENT	10	35	23	0	2	0
INVOLVING TRACK UNIT	0	0	0	0	0	0
DG LEAKER	0	0	0	0	0	0
EMPLOYEE	0	0	0	0	0	0
FIRE	0	0	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	3	19	19	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1	1	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	1	1	0	0	0	0
R/S COLL. WITH OBJECT	1	1	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0	0	0
TRESPASSER UNPROTECTED	1	1	0	0	1	1
OVERLAP OF AUTHORITIES	1	1	0	0	0	0
Grand Total	**19**	**60**	**42**	**0**	**3**	**1**

Table A-87 Severity indicators (2007 - 2016) at the Wynyard subdivision.

Subdivision	WYNYARD		ETC L 1	1		
			Preventability			
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**Occurrence with serious injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	0	0	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING	0	0	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0	0	0
DG LEAKER	0	0	0	0	0	0
EMPLOYEE	0	0	0	0	0	0
FIRE	0	0	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1	1	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0	0	0
TRESPASSER UNPROTECTED	0	0	0	0	0	0
OVERLAP OF AUTHORITIES	0	0	0	0	0	0
Grand Total	**1**	**1**	**0**	**0**	**0**	**0**

Table A-88 Severity indicators (2007 - 2016) that could have been prevented by ETC L1 at the Wynyard subdivision.

Subdivision	WYNYARD		ETC L 3	1		
			Preventability			
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**Occurrence with serious injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	0	0	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING	0	0	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0	0	0
DG LEAKER	0	0	0	0	0	0
EMPLOYEE	0	0	0	0	0	0
FIRE	0	0	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1	1	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0	0	0
TRESPASSER UNPROTECTED	0	0	0	0	0	0
OVERLAP OF AUTHORITIES	0	0	0	0	0	0
Grand Total	**1**	**1**	**0**	**0**	**0**	**0**

Table A-89 Severity indicators (2007 - 2016) that could have been prevented by ETC L3 at the Wynyard subdivision.

Subdivision	WYNYARD		ETC L 4	1		
			Preventability			
Occurrence group	**Occurrences**	**Rolling stock involved**	**Rolling stock derailed**	**Dangerous goods cars involved**	**occurrence with serious Injuries**	**Fatalities**
COLLISION INVOLVING TRACK UNIT	0	0	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0	0	0
CROSSING	0	0	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0	0	0
DG LEAKER	0	0	0	0	0	0
EMPLOYEE	0	0	0	0	0	0
FIRE	0	0	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1	1	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0	0	0
TRESPASSER	0	0	0	0	0	0
UNPROTECTED OVERLAP OF AUTHORITIES	1	1	0	0	0	0
Grand Total	**2**	**2**	**0**	**0**	**0**	**0**

Table A-90 Severity indicators (2007 - 2016) that could have been prevented by ETC L4 at the Wynyard subdivision.

Severity indicators - factual and potential reduction if ETC implemented

WYNYARD	No. Occurrences			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	10	10	10	10
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	0	0	0	0
EMPLOYEE	0	0	0	0
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	1	1
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	3	3	3	3
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	1	1	1	1
R/S COLL. WITH OBJECT	1	1	1	1
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	1	1	1	1
UNPROTECTED OVERLAP OF AUTHORITIES	1	1	1	0
Grand Total	**19**	**18**	**18**	**17**

Table A-91 No. occurrences (2007 - 2016) and its reduction if ETC had been implemented at the Wynyard subdivision.

WYNYARD	No. rolling stock involved			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	35	35	35	35
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	0	0	0	0
EMPLOYEE	0	0	0	0
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	1	1	1	1
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	19	19	19	19
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	1	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	1	1	1	1
R/S COLL. WITH OBJECT	1	1	1	1
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	1	1	1	1
UNPROTECTED OVERLAP OF AUTHORITIES	1	1	1	0
Grand Total	**60**	**59**	**59**	**58**

Table A-92 No. rolling stock involved (2007 - 2016) and its reduction if ETC had been implemented at the Wynyard subdivision.

WYNYARD	No. rolling stock derailed			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	23	23	23	23
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	0	0	0	0
EMPLOYEE	0	0	0	0
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	19	19	19	19
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	0	0	0	0
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**42**	**42**	**42**	**42**

Table A-93 No. rolling stock derailed (2007 - 2016) and its reduction if ETC had been implemented at the Wynyard subdivision.

WYNYARD	No. dangerous goods cars involved			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	0	0	0	0
EMPLOYEE	0	0	0	0
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	0	0	0	0
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**0**	**0**	**0**	**0**

Table A-94 No. dangerous goods cars involved (2007 - 2016) and its reduction if ETC had been implemented at the Wynyard subdivision.

WYNYARD	No. occurrences with serious injuries			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	2	2	2	2
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	0	0	0	0
EMPLOYEE	0	0	0	0
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	1	1	1	1
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**3**	**3**	**3**	**3**

Table A-95 No. occurrences with serious injuries (2007 - 2016) and its reduction if ETC had been implemented at the Wynyard subdivision.

WYNYARD	No. fatalities			
Occurrence group	**Before ETC**	**After ETC L 1**	**After ETC L 3**	**After ETC L 4**
COLLISION INVOLVING TRACK UNIT	0	0	0	0
CREW MEMBER INCAPACITATED	0	0	0	0
CROSSING	0	0	0	0
DERAILMENT INVOLVING TRACK UNIT	0	0	0	0
DG LEAKER	0	0	0	0
EMPLOYEE	0	0	0	0
FIRE	0	0	0	0
MAIN-TRACK SWITCH IN ABNORMAL POSITION	0	0	0	0
MAIN-TRACK TRAIN COLLISION	0	0	0	0
MAIN-TRACK TRAIN DERAILMENT	0	0	0	0
MOVEMENT EXCEEDS LIMITS OF AUTHORITY	0	0	0	0
R/S COLL. WITH ABANDONED VEHICLE	0	0	0	0
R/S COLL. WITH OBJECT	0	0	0	0
R/S DAMAGE WITHOUT DERAIL./COLL.	0	0	0	0
RUNAWAY ROLLING STOCK	0	0	0	0
SIGNAL LESS RESTRICTIVE THAN REQUIRED	0	0	0	0
TRESPASSER	1	1	1	1
UNPROTECTED OVERLAP OF AUTHORITIES	0	0	0	0
Grand Total	**1**	**1**	**1**	**1**

Table A-96 No. fatalities (2007 - 2016) and its reduction if ETC had been implemented at the Wynyard subdivision.