

Chiltern Route Train Protection - Railway Safety Regulations 1999 Exemption Application Report



1 Executive Summary

- 1.1. This report explains the reasoning and justification supporting Network Rail Infrastructure Limited (NR) application in association with The Chiltern Railway Company Limited (CRCL), for an exemption from the requirement under Regulation 3 of the Railway Safety Regulations (1999); that a train should be fitted with a train protection system (as defined by Regulation 2).
- 1.2. This exemption application applies between Marylebone and Aynho Junction on the Chiltern Mainline where it is proposed that train protection will be provided by Enhanced Train Protection Warning System (TPWS) that will be delivered to provide a comparable level of protection to existing SELCAB ATP for CRCL services until longer term plans for ETCS operation can be confirmed.
- 1.3. The exemption application applies only in relation to CRCL services and will only be utilised until ETCS or another Train Protection System is installed and available for the passenger operations between London Marylebone and Aynho Junction.
- 1.4. The continued operation of CRCL services offer significant passenger and societal benefits outside of those considered within the Regulations making the operation of the CRCL service still a priority.
- 1.5. Several issues have arisen and materialised making maintaining the current SELCAB ATP system in the area between Marylebone and Aynho Junction a non-viable solution. Issues on both the on-train equipment and infrastructure have included (but not limited to):
 - Supplier withdrawing support;
 - Limited equipment availability and;
 - Limited experience and competence in the UK of the ATP system.
- 1.6. A revised strategy for Train Protection has been developed in line with NRs Governance of Railway Investment Projects (GRIP) and the Common Safety Method for Risk Evaluation and Assessment (CSM-RA) framework (the statutory risk management process for the mainline railway) for the reasons above.
- 1.7. In the development of this selected option a number of delivery scenarios and outline system definitions were developed in line with The Office of Rail and Road (ORR) guidance. To inform industry members reviewing and selecting options we have:
 - Developed a range of initial options for appraisal (including options that would not require an exemption);
 - Analysed each option against a number of safety, feasibility, performance and cost criteria; and
 - Undertaken extensive stakeholder engagement.
- 1.8. From the range of options available, it was concluded that Enhanced TPWS and upgrading trains to TPWS Mk4 is an appropriate Train Protection System solution for operation until 31st December 2027 as it would (but is not limited to):

- achieve similar levels of overrun protection to SELCAB ATP;
 - use a known, proven and reliable technology;
 - enable use of standard migration principles to ETCS;
 - deliver benefits within the shortest timescale; and
 - allow delivery of a more resilient railway.
- 1.9. Enhanced TPWS and upgrading trains to TPWS Mk4 was found to offer a similar level of signal overrun protection to the current ATP/TPWS arrangements following detailed analysis.
- 1.10. Enhanced TPWS will not inhibit or delay future ETCS deployment and will permit the national migration method from TPWS for train and infrastructure.
- 1.11. NR and CRCL are keen to progress this application for exemption with the ORR, and will fully participate in any public consultation that the ORR considers appropriate to ensure the best outcome for users of, and stakeholders in, the rail network.
- 1.12. NR and CRCL are totally committed to delivering TPWS enhancements for Marylebone to Aynho Junction. The ORR is requested to grant a certificate for temporary exemption under Regulation 6 of the Railway Safety Regulations 1999 in respect of the train protection requirements of Regulation 3 of those Regulations. This exemption would be required to permit operation of Class 165/0, Class 168/0/1/2 and Class 172/1 trains by CRCL from 1st January 2023 to 31st December 2027 on the area of Chiltern Route detailed below until longer term plans for ETCS operation can be confirmed:
- Marylebone to Aynho Junction. (MCJ1 205m77ch to NAJ3 18m30ch Up Lines and 18m35ch Down Lines)
 - Princes Risborough to Aylesbury (PRA 42m31ch to 49m 35ch Down & Up Aylesbury line)
 - Neasden South Junction to LU/NR Boundary (MCJ1 197m 5ch to 200m 65ch Up & Down Harrow Lines)
 - Aylesbury to LU/NR Boundary (MCJ2 38m 13ch to 25m 21ch Up & Down Mains)
 - Aylesbury Vale Parkway to Aylesbury (MCJ2 40m 38ch to 38m 13ch Up & Down Aylesbury Line)
- 1.13. The operation of train protection on the Chiltern route during the exemption period will be carried out in accordance with the Chiltern Route Train Protection - Railway Safety Regulations 1999 Exemption Operational Safety Plan – R362 (Reference 5).
- 1.14. A complementary temporary exemption under Regulation 6 of the Railway Safety Regulations 1999 in respect of the train protection requirements of Regulation 3 of those Regulations is being proposed by CRCL with support from NR for the period from 1st July 2020 until 30th June 2024. (See SELCAB ATP Short Term RSR 1999 Exemption Summary Report – R363 (Reference 4)). This exemption report covers the continuing operation of CRCL services in the case the ATP system cannot be kept operational on all of its fleets and during the period that Enhanced TPWS and upgrading trains to TPWS Mk4 is being implemented.

- 1.15. There is an overlap in the exemptions from 1st January 2023 until 30th June 2024 for the period when it is expected that the ATP system will be removed from service and this exemption will come into force.

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2 Introduction

2.1 Purpose

- 2.1.1 This report summarises Network Rail Infrastructure Limited's (NR) application under Regulation 6 of the Railway Safety Regulations 1999 (RSR99) in association with The Chiltern Railway Company Limited (CRCL), for exemption from the requirement under Regulation 3 that a train shall be fitted with a train protection system (as defined by Regulation 2).
- 2.1.2 This exemption application is required to support use of train protection arrangements for a limited period on services to be operated in the area between London Marylebone and Aynho Junction on the Chiltern Route, part of the North West & Central Region. This proposal will need to be implemented when CRCL uses Class 165/0 Networker Turbo, Class 168/0/1/2 Clubman, Class 172/1 Turbostar trains without SELCAB ATP.
- 2.1.3 The exemption will be utilised by NR and CRCL to operate using TPWS, that will be upgraded to Enhanced TPWS and upgrading trains to Mk4 TPWS as the train protection system for all or part of the route from Marylebone and Aynho Junction.
- 2.1.4 The exemption, if granted, will mitigate the impact of any delays or service cancellations due to the failure and obsolescence of ATP and thus improve the resilience of the Chiltern Route.
- 2.1.5 It is felt prudent by NR, and CRCL that we should secure such an option, to ensure adequate train protection is in place for the continued operation of CRCL services

2.2 Scope

- 2.2.1 This exemption application applies to CRCL passenger services operating Class 165/0 Network Turbo, Class 168/0/1/2 Clubman, Class 172/1 Turbostar trains in the following areas of Chiltern route:
- Marylebone Station to Aynho Junction (MCJ1 205m77ch to NAJ3 18m30ch Up Lines and 18m35ch Down Lines)
 - Princes Risborough to Aylesbury (PRA 42m31ch to 49m 35ch Down & Up Aylesbury line)
 - Neasden South Junction to LU/NR Boundary (MCJ1 197m 5ch to 200m 65ch Up & Down Harrow Lines)
 - Aylesbury to LU/NR Boundary (MCJ2 38m 13ch to 25m 21ch Up & Down Mains)
 - Aylesbury Vale Parkway to Aylesbury (MCJ2 40m 38ch to 38m 13ch Up & Down Aylesbury Line)

2.3 Timescale

- 2.3.1 This exemption is required to permit the full implementation of Enhanced TPWS and MK4 TPWS onboard fitment as an alternative to SELCAB ATP so that SELCAB ATP

to be removed from service. Therefore, exemption is applied for the period from 1st January 2023 up to and including to 31st December 2027.

- 2.3.2 A complementary exemption application report, SELCAB ATP Short Term RSR 1999 Exemption Summary Report – R363(Reference 4), has been prepared in parallel by CRCL. This report is supported by NR, and supports continued operation of trains if the SELCAB ATP system fails during the period 1st July 2020 until 30th June 2024, during the implementation of Enhanced TPWS and MK4 TPWS onboard fitment.
- 2.3.3 CRCL current franchise ends 31st December 2021, with an option to extend for up to 5 years.
- 2.3.4 Application is made until 31st December 2027 beyond end of current and any extension to CRCL franchise to allow for potential planned ETCS operation to be agreed and implemented after 31st December 2026.
- 2.3.5 Current deployment date for ETCS on the route would after 2035 in Control Period 9 based on the Digital Long Term Deployment Plan.

2.4 Abbreviations and Definitions

- 2.4.1 Abbreviations have been avoided as far as possible in this report, and where they are used they are defined within the text. The list below provides a summary of the abbreviations and definitions used:

AsBo - Assessment Body

ATO - Automatic Train Operation

ATP - Automatic Train Protection

Balise/Beacon/Loop (in the context of this document) - track mounted equipment in a specific position that communicates with an on train system. Balise is French for beacon

CBTC - Communications Based Train Control

Ch - Chain (An imperial measurement equal to 22 yards)

CRCL – The Chiltern Railway Company Limited (“Chiltern Railways”), Company registration number: 3007939.

CSM-RA - Common Safety Method on Risk evaluation and Assessment

DMU - Diesel Multiple Unit

Enhanced TPWS – TPWS system whose effectiveness is improved by additional trackside equipment

ERTMS - European Rail Traffic Management System

ETCS - European Train Control System

EVC - European Vital Computer

FWI - Fatality Weighted Injuries

GRIP - Governance of Railway Investment Projects

GW-ATP - Great Western Automatic Train Protection

GWML - Great West Main Line

HAZID – A Hazard Identification process

HS2 - High Speed 2

HST – High Speed Train

LED – Light Emitting Diode

LUL – London Underground Limited

LZB - Linenezugbeeinflussung (an ATP system used in Germany, Austria and parts of Spain)

MAF-SD – Splitting distant, junction signal control

MAR – Approach release from red, junction signal control

MAY-FA – Flashing Aspect, junction signal control

Movement Authority – Indication to driver of permission to enter a section of line

MP - Mile Post

MTBSAF - Mean Time Between Service Affecting Failures

NR - Network Rail Infrastructure Limited (Company registration number: 02904587)

OL – Overlap. Safety zone beyond each stop signal

ORR – Office of Rail and Road

OTDR – On-Train Data Recorder

OSS – Over Speed System

Permissive move - movement of train into platform already occupied by another train

Perturbed operation - any time when the train service is delayed or disrupted from the normal operational timetable

PSR – Permanent Speed Restriction

RBC – Radio Block Centre

Regulated PSR - Speed reductions of 1/3 or more and initial speed of 60mph or more.

RSR99 - Railway Safety Regulations 1999

SOD - Safe Overrun Distance

SORAT - Signal Overrun Assessment Tool

SPAD – Signal Passed at Danger

SRM – Safety Risk Model

Standard TPWS - TPWS fitted in line with current standards

TBD – To Be Determined

Tph - Trains Per Hour

TPWS - Train Protection Warning System

TSI CCS - Technical Specification for Interoperability for Command, Control & Signalling

TSS – Train Stop System

3 Background

3.1 The Chiltern Route (overview)

3.1.1 CRCL operate the mainline services on the Chiltern Mainline between London Marylebone and the West Midlands through the M40 corridor. Recent service additions have included a new chord connecting to a new station at Oxford Parkway and Oxford (see figure 1).

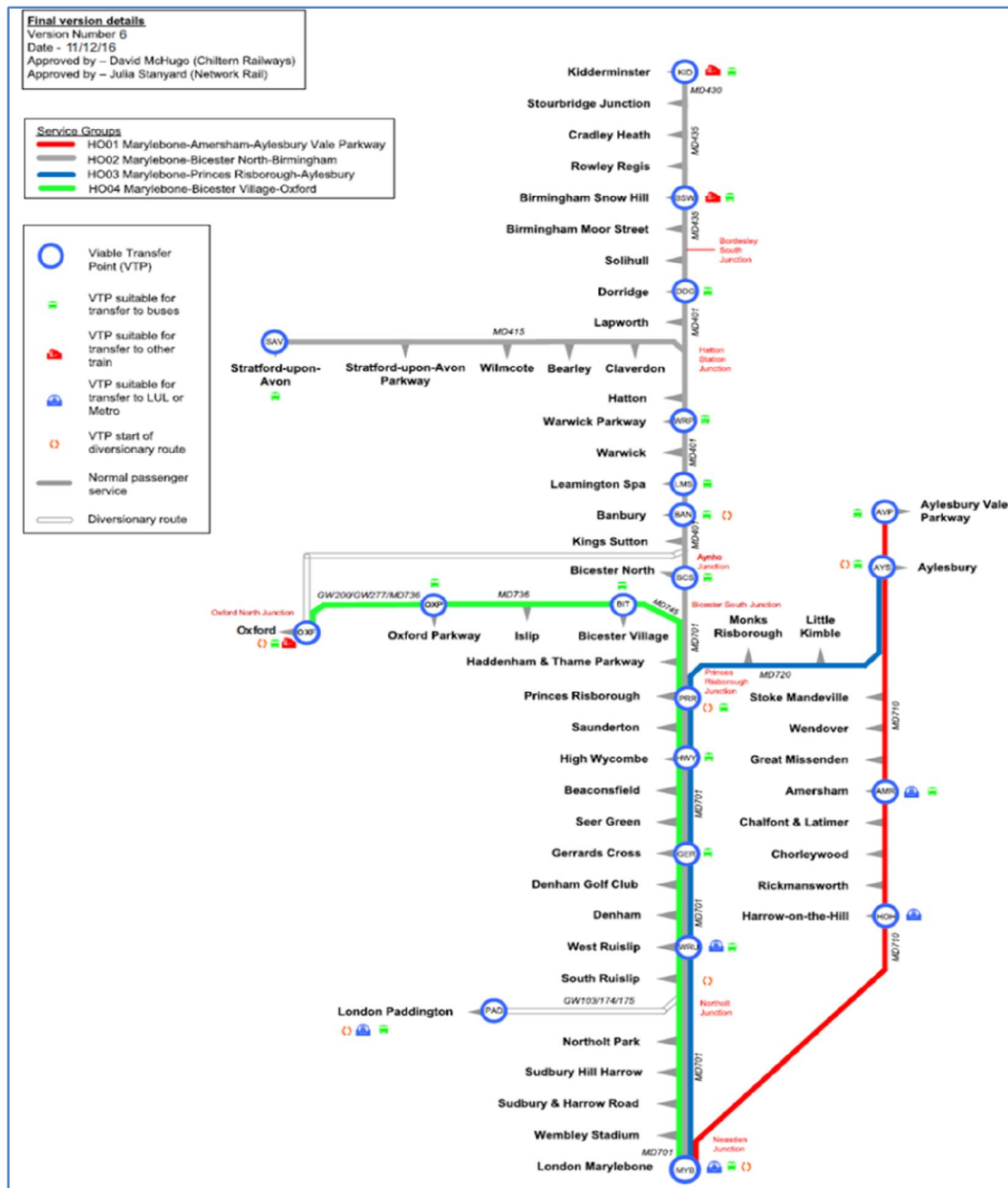


Figure 1

3.2 Exemption area (Overview)

3.2.1 The exemption application applies to the following areas of Chiltern & Central route (see figure 2 below):

- London Marylebone and Aynho Junction
- Connection section of Harrow Line on the Hill (LUL boundary) to Neasden South Junction
- Connection section of Wycombe Line to Northolt Junction
- Between Aylesbury Vale Parkway and Amersham (LUL boundary)
- Between Princes Risborough and Aylesbury
- Bicester South West Chord

3.2.2 The area is largely two tracks used by non-stopping passenger services, local stopping passenger services and freight.

3.2.3 Marylebone Station has six platforms accessed from the Up and Down Main lines.

3.2.4 Depot facilities are provided at Aylesbury and Wembley.

3.2.5 Maximum speed on the line is 100mph.

3.3 Chiltern Railway Trains

3.3.1 CRCL trains operate a fleet of mixed-use diesel traction (Class 165/0 Network Turbo, Class 168/0/1/2/3 Clubman, Class 172/1 Turbostar, Class 68, Mk3 Coaching Stock, Class 82 Driving Van Trailer) over the route using TPWS as the main form of train protection.



3.3.2 SELCAB ATP is fitted to selected Diesel Multiple Units (DMUs) for use on the sections as detailed in Section 3.4. and provides additional train protection.

3.3.3 Locomotives and Class 82 DVT were introduced to the mainline passenger services in pull-push configuration without SELCAB ATP in 2011. Currently these are operated by Class 68 locomotives.

3.3.4 More recently the Class 168/3 have been added to the fleet that also operate without SELCAB ATP.

3.3.5 Currently CRCL have a total fleet of 76 sets, 62 of these operate with SELCAB ATP.

3.4 Chiltern Route Train Protection

3.4.1 Chiltern Route operates with TPWS and AWS train protection on the entirety of the route between London and the West Midlands.

3.4.2 Between Marylebone and Aynho Junction most signals are also fitted with SELCAB ATP Figure 2 shows the areas where SELCAB ATP is used in addition to TPWS.

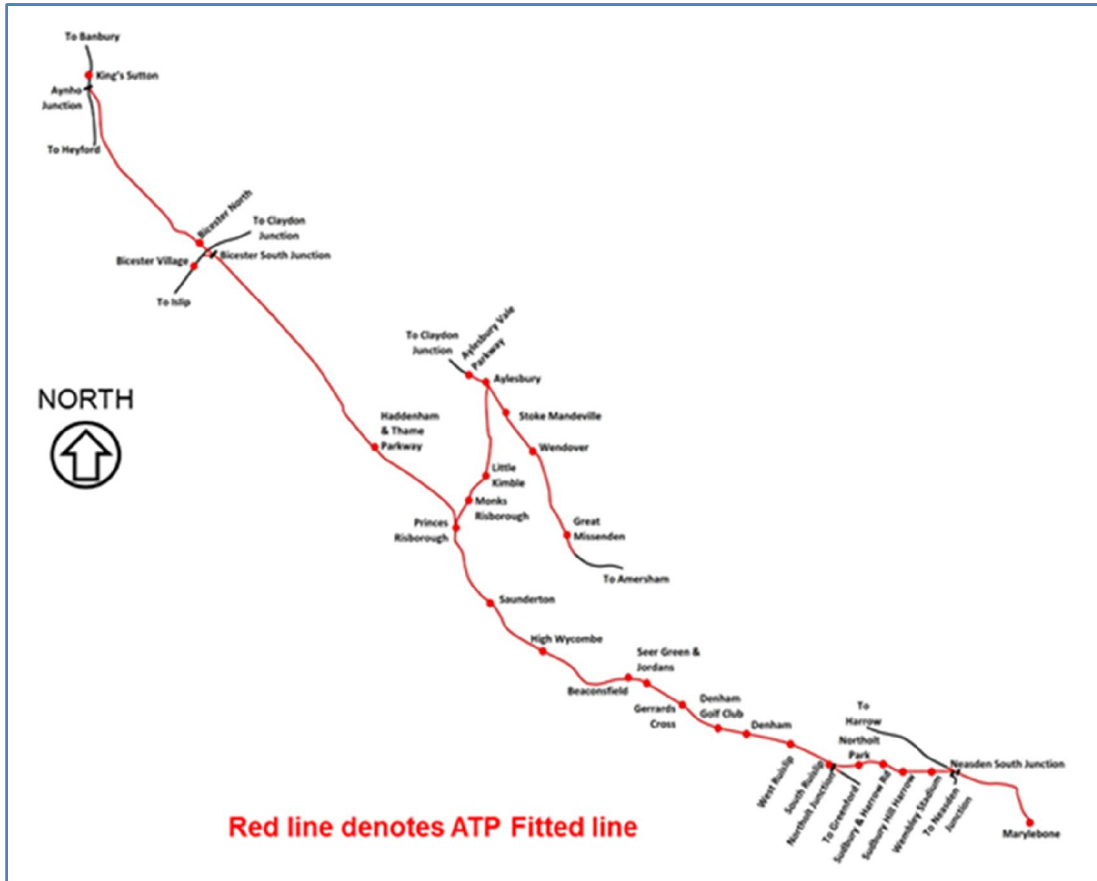


Figure 2

- 3.4.3 SELCAB ATP was installed initially as a pilot system by British Railways in the 1990s to evaluate ATP operations for suburban routes.
- 3.4.4 When originally implemented, all Class 165/0 DMUs operating in the area were fitted with SELCAB-ATP. Other trains and routes had no train protection systems at that time. TPWS was fitted to the area as part of the national programme across all routes in 2003/4, following introduction of the RSR99, Regulation 2 and 3, meaning all trains on the route were now covered by some form of train protection system.
- 3.4.5 Currently the infrastructure in the relevant area supports both SELCAB-ATP and TPWS operation. All of the trains using this infrastructure are equipped with either one or both of these solutions (see section 4.7, Train Types and Services)

3.5 Regulation History

- 3.5.1 Wide ranging recommendations were made in the report by Sir Anthony Hidden QC into the rail accident at Clapham Junction (1988 - 35 deaths) (Hidden Report).

- 3.5.2 The Hidden Report called for national implementation of Automatic Train Protection (ATP) to be completed within 10 years. This recommendation was made following significant and tragic rail accidents caused by signals passed at danger (SPAD) at Purley (1989 - five deaths) and Bellgrove (1989 – two deaths). Both these accidents and a spate of other near-misses could have been prevented by ATP.
- 3.5.3 Rolling stock design problems were also identified in the Hidden Report as a contributing factor to the number of fatalities suffered in accidents at Clapham Junction, Hither Green and Cannon Street.
- 3.5.4 In reply to the Hidden Report’s recommendations two UK pilot schemes of ATP took place. British Rail and then Railtrack carried out extensive analysis and consultation into whether ATP should retrospectively be fitted nationally. It was decided by Railtrack, accepted by the Government, that ATP would not be implemented nationally. Both ATP pilot systems remained in place but were not mandated as essential parts of the signalling system.
- 3.5.5 In 1994, following the decision by British Rail not to retrospectively fit ATP across the network, Railtrack (now Network Rail) set up a project to examine alternative ways of preventing and reducing SPADs. An output of this work-stream was the development of the Train Protection and Warning System (TPWS).
- 3.5.6 At Southall in September 1997, a High Speed Train passed a signal at danger (SPAD) and crashed into a freight train, resulting in seven deaths. The line on which this occurred was fitted with GW-ATP but the system was not operational.
- 3.5.7 At Ladbroke Grove in October 1999, again on a line on which GW-ATP was fitted, a SPAD resulted in a local passenger train proceeding without authority along the main line leading to a major collision with a HST. The collision resulted in 31 deaths, with many more severely injured. Although the line and HST were fitted with operational GW-ATP, the local train that passed the stop signal was not.
- 3.5.8 The Southall and Ladbroke Grove collisions acted as a catalyst for the national deployment of TPWS to both track and train, through the creation of the National TPWS Project. Ladbroke Grove raised the urgency of further legislation dealing with the issues raised in the Hidden Report, in addition to accelerating the provision of TPWS nationwide.

3.6 Relevant Regulations

- 3.6.1 Following the Southall and Ladbroke Grove collisions attitudes to regulation of the railway industry changed. Making installation of a train protection system mandatory was now seen as necessary to achieve full national coverage. Recommendations from several inquiries were rolled up into a single Statutory Instrument, which required what were by now considered a series of essential safety upgrades. The Railway Safety Regulations 1999 had three principal aims:
- compulsory use of a train protection system;
 - prohibition of the use of Mark 1 rolling stock; and
 - prohibition of the use of hinged door rolling stock.

3.6.2 Regulation 3 of RSR99 sets out the requirement to have a train protection system in service on a train, whereas Regulation 2 defines what this means:

Use of a train protection system

3.—(1) No person shall operate, and no infrastructure controller shall permit the operation of, a train on a railway unless a train protection system is in service in relation to that train and railway.

Regulation 3

“train protection system” means equipment which—

- (a) causes the brakes of the train to apply automatically if the train—
 - (i) passes without authority a stop signal such passing of which could cause the train to collide with another train, or
 - (ii) travels at excessive speed on a relevant approach;
- (b) is installed so as to operate at every stop signal referred to in sub-paragraph (a), except a stop signal on the approach to an emergency crossover, and at an appropriate place on every relevant approach;
except that where it is reasonably practicable to install it, it means equipment which automatically controls the speed of the train to ensure, so far as possible, that a stop signal is not passed without authority and that the permitted speed is not exceeded at any time throughout its journey.

Regulation 2 (extract)

3.6.3 In broad terms (a) and (b) define the functions offered by TPWS. As such TPWS is a train protection system, but only if a system that automatically controls the speed of a train, ATP, is not reasonably practicable to install. So TPWS is a compliant train protection system if it is not reasonably practicable to install ATP.

4 Train Protection Systems

4.1 Introduction

4.1.1 Train protection systems act to prevent or mitigate the risk of a train exceeding safe limits. To achieve this, systems automatically apply a train's brakes should a driver pass a stop signal at danger or exceed speed limits on approach to a signal. Systems can also prevent a train's speed exceeding that permitted on specific sections of the route and at junctions.

4.1.2 Train protection systems supervision can provide either "intermittent" (new information only available at specific sites) or "continuous" (information always capable of being updated).

- Intermittent - checks the movement authority and can check the speed of trains at predetermined locations. TPWS, SELCAB-ATP and ETCS L1 are intermittent systems, but-SELCAB-ATP and ETCS L1 do continuously monitor speeds.
- Continuous - verifies the movement authority of trains through their entire journey, which can be changed at any time to stop a train if an unsafe condition arises (such as another train exceeding its movement authority) and requires continuous updated signalling system information to the train.

4.1.3 Train protection can be grouped into three broad categories;

- Basic (Train Protection) - protection at selected locations, can include selective speed supervision e.g. mechanical Trainstops and TPWS;
- Beacon based (ATP) - protection at selected locations, plus provides running profile (speed and distance) going forwards. e.g. GW-ATP; and
- Continuous (ATP) - Provides protection of speed and movement authority throughout. e.g. ETCS L2, CBTC.

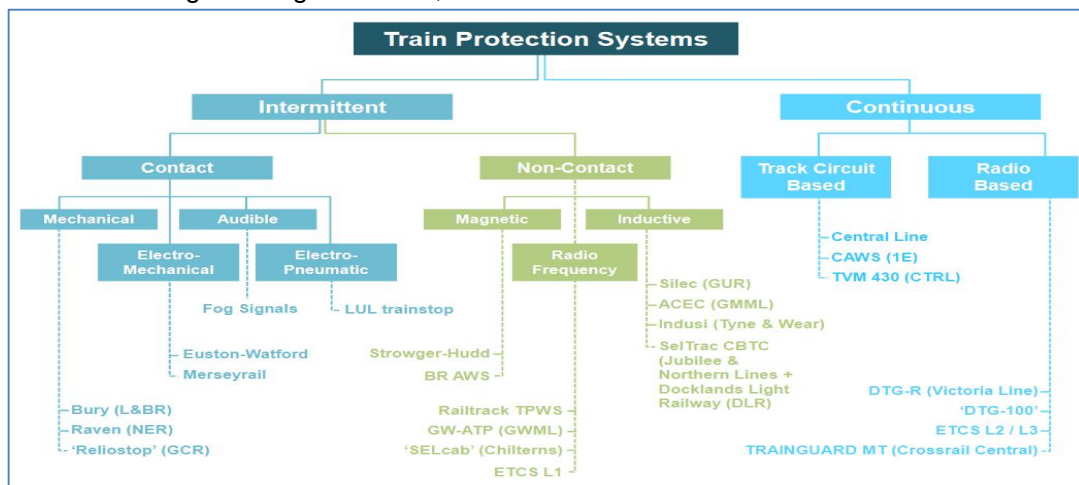


Figure 3

4.1.4 Figure 3 shows various types of train protection systems in broad categories.

- 4.1.5 The term ATP (Automatic Train Protection) is applicable to systems that provide some kind of automated protection that stops a train that has exceeded the signalled movement authority (SPAD). These systems also can also prevent trains over-speeding; this is either on a location selective basis, or for the more advanced ATP systems continuous speed supervision is provided. Over-speeding either results in the train being brought to a stop or being returned to the correct authorised speed.
- 4.1.6 Automatic Warning System (AWS) is in use throughout NR. AWS primarily provides a warning to drivers of signal aspects that require the train to slow down or stop at a signal. AWS is fundamentally a warning system as brake application can be overridden by the driver. The warning acts as a driver aid to assist safe operation by requiring acknowledgment of a signal aspect that requires a driver to take action. Whilst AWS aids safe operation, it provides very limited train protection functionality as if a warning is not acknowledged the trains' brakes are applied, but is not considered a train protection system under RSR99.
- 4.1.7 Another example of a widely used intermittent type system would be that which makes physical contact with a component on the train, such as the Trainstop/Trip Cock systems used on London Underground and some NR lines. E.g. Mersey Rail, Euston DC Lines. When the Trainstop on the track makes contact with the train's Trip Cock the brakes are automatically applied.
- 4.1.8 TPWS is an intermittent loop based system used on most of the UK rail network and is described in section 4.2 of this document.
- 4.1.9 SELCAB ATP is a loop based system, which is further described in section 4.3 of this document.
- 4.1.10 ETCS (Level 2 and 3) are continuous forms of ATP, which are also further described in sections 4.4 of this document.

4.2 TPWS – what is it?

- 4.2.1 TPWS is a system designed to reduce the number of, and in particular to mitigate the consequences of, SPADs and buffer-stop collisions. Pairs of transmitter loops are provided at each site that emit specific frequencies appropriate to their respective roles of “Arming Loop” and “Trigger Loop” (see Figure 4). An on-board aerial picks up the emitted frequencies as the front of a train passes over the loops and the receiver then determines whether to initiate a brake application on the train. Brake demand is based upon the specific frequencies detected and the time interval between receiving them.

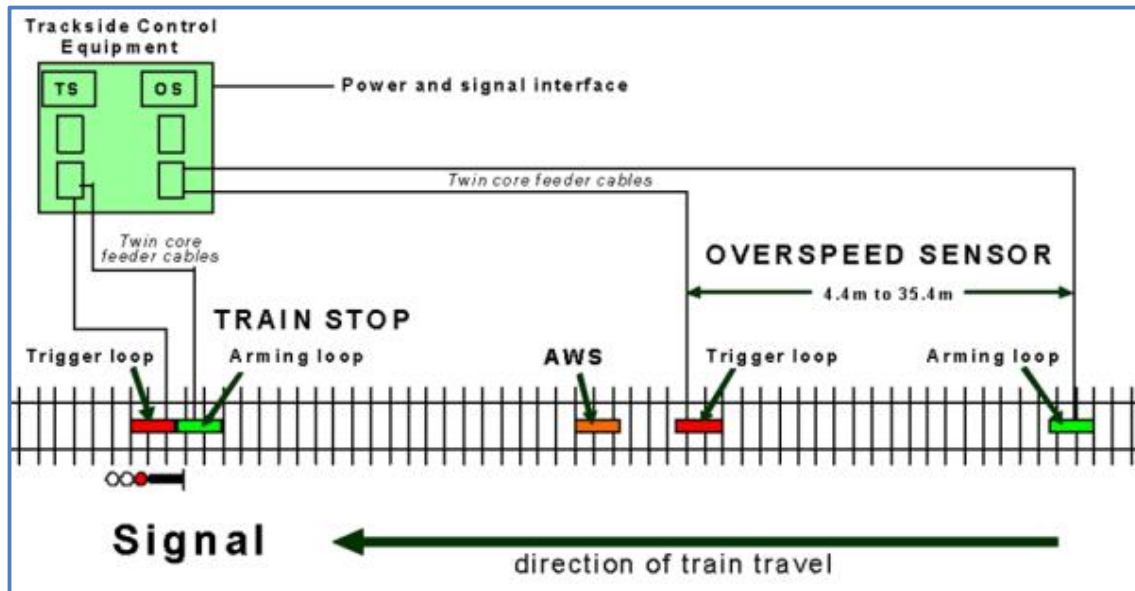


Figure 4

- 4.2.2 A Train Stop System (TSS) function is created by placing the Arming Loop immediately before the Trigger Loop placed (generally) at a stop signal. TSS loops emit frequencies when the signal is displaying a stop aspect. Should a train pass over the TSS loops, a full emergency brake application occurs until the train is brought to a standstill. TPWS is generally applied only to those signals that protect junctions, so is not provided at every signal.
- 4.2.3 An Overspeed Sensor System (OSS) function is created by placing the Arming Loop a calculated distance before the Trigger Loop; this loop separation determines the set speed of the OSS loops. OSS loops are provided on the approach to buffer-stops, some permanent speed restrictions (PSR) and most signals fitted with TSS.
- 4.2.4 When a train detects the Trigger frequency within a critical time period following detection of the Arming frequency, the result is a full emergency brake application until the train is brought to a standstill. Hence an OSS acts as a speed check, applying the brakes should a train be approaching a buffer stop, PSR or signal at danger at an excessive speed.
- 4.2.5 The on-board timer of freight trains is set at a longer value than for passenger trains; this reflects lower braking performance necessitating a more cautious approach to the signal at danger. Thus OSS loops check freight trains at lower speeds than passenger trains.
- 4.2.6 TPWS was chosen for national implementation for the following reasons:
- TPWS is a capable and cost effective means of addressing the majority of the risk associated with SPADs;
 - TPWS was capable of speedy introduction avoiding protracted development and extended safety approval timescale; and

- TPWS provides immediate safety benefits after installation; the rolling stock could be modified, and each signal fitment commissioned independently.

4.2.7 TPWS only requires an active train and an installed loop to work for a given signal; there is no requirement for an extensive network. TPWS is a very effective train stop system but has some limitations as a speed supervision system. This is especially apparent when there is a mix of rolling stock characteristics and TPWS is attempting to act as a speed trap on the approach to a speed restriction or at a great distance from a signal.

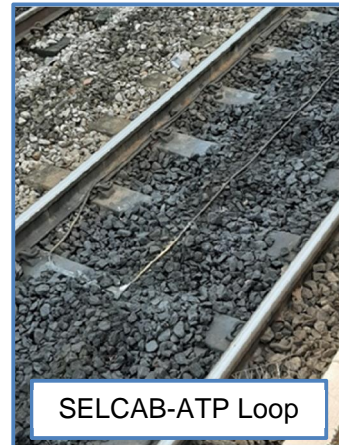
Enhanced TPWS

- 4.2.8 TPWS is an expandable system; additional loops are able to be provided on the approach to a signal, buffer stop or speed restriction there by reducing the intermittency of supervision. With an increased number of loops the system becomes more continuous. Such enhancements mean TPWS can be made to more closely match the functionality provided by SELCAB ATP.
- 4.2.9 Enhanced TPWS adds TSS loops at signals not fitted with TPWS, and OSS loops designed to stop a train short of a conflict.
- 4.2.10 Enhanced TPWS is designed to afford maximum protection available from TPWS for CRCL services. This will be further optimised during its implementation to provide optimum protection for ALL trains operating over the Enhanced TPWS. This provision shows significant safety benefit from the increased TPWS provision, particularly at sites currently not fitted with TPWS at all or only had a single OSS loop.
- 4.2.11 Enhanced TPWS will also upgrade all on-train TPWS equipment to the most recent design standard as detailed in RIS-0775-CCS and GE/RT8075. This is also known as Mk4 TPWS. The majority of the Chiltern Railways fleet is fitted with earlier designed TPWS equipment. The newer equipment has design changes that have improve the effectiveness of TPWS.

4.3 SELCAB ATP - what is it?

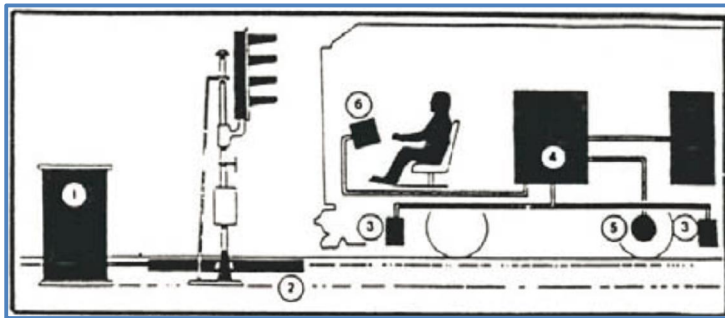
- 4.3.1 UK trials of ATP took place in Britain following the Clapham accident. British Rail and then Railtrack carried out extensive analysis and consultation into whether ATP should retrospectively be fitted to the UK rail network. The conclusion of the trials was that the costs and risks of retrofitting ATP nationally were grossly disproportionate when compared to the safety benefits that would be realised.

4.3.2 The SELCAB ATP system trialled was based on the German LZB system and installed on the lines between London Marylebone and Anyho Junction. The system incorporates comprehensive speed and position measurement technology and links into the lineside signals so the system knows the status of the line ahead. This information is transmitted to the train via a series of beacons and transmitter loops. A similar system is in place on the Great Western Main Line. These were the only ATP installations on the UK main line network until ETCS was installed as a trial on the Cambrian route in Wales in the early 2000s.



SELCAB-ATP Loop

4.3.3 SELCAB-ATP on-board equipment continuously monitors the speed of the train against permitted line speed, which can be intermittently updated. An on-board computer determines whether the train is going too fast, and automatically applies the brake where necessary. SELCAB-ATP removes the risk of drivers ignoring or cancelling warnings.



- 1 Trackside equipment location
- 2 Transmitting loop at signal
- 3 Receiving aerial
- 4 Computer and train interface
- 5 Odometry (speed / distance)
- 6 Driver's display

4.3.4 The general principle of the system is that the driver is still required to observe lineside signals but is given an indication of the target speed using LEDs associated with the speedometer.

4.3.5 An audible warning is given if the speed limit is infringed. If the driver fails to reduce speed the system will apply the brakes. Once the train speed has reduced below the maximum permitted (target) speed, the system allows the driver to take control of the train. ATP constantly polices observation of the speed limit and the braking distance required; it is constantly recalculating the correct speed at which the train should be travelling.



SELCAB Speedometer

4.4 ERTMS/ETCS - what is it?

4.4.1 The European Rail Traffic Management System (ERTMS), of which the European Train Control System (ETCS) is part, is the legally mandated train control and protection system intended to achieve railway interoperability and compatibility throughout the European rail network. ERTMS will offer many benefits to the railway through the application of its cab signalling and train protection component.

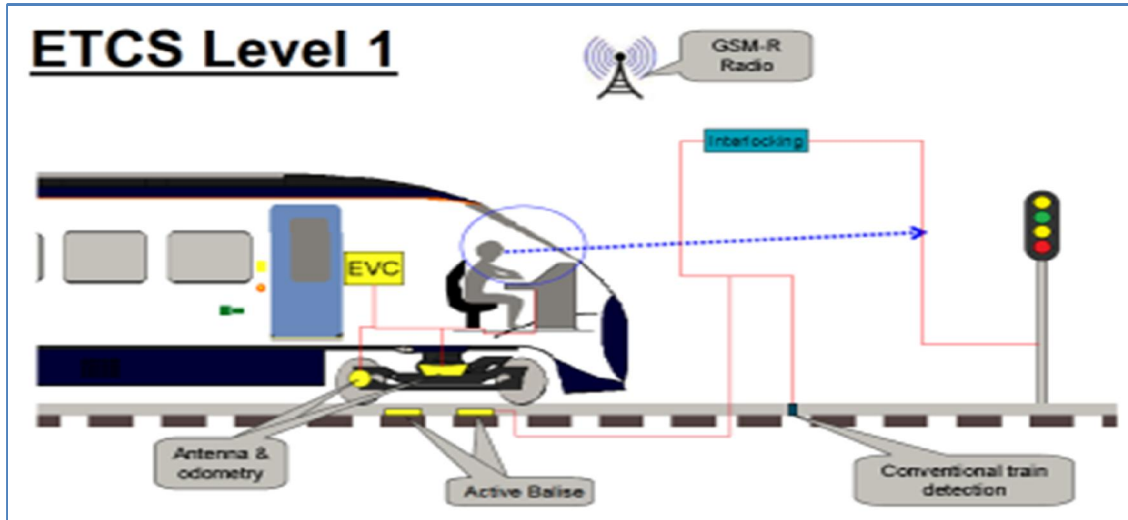
4.4.2 ERTMS is composed of four component parts:

- European Train Control System (ETCS) - The train control element which provides ATP. ETCS is not in itself a signalling system, but is a component part of the signalling system;
- Global System for Mobile communications – Railways (GSM-R) - This is the telecommunications element of ERTMS for data and voice communications;
- European Traffic Management Layer - The command element which is used to optimise operations through improved management of train running to maximise utilisation and reduce scheduling conflicts; and
- European Operational Rules (EOR) – A single rule set designed to standardise certain aspects of rail operation across Europe.

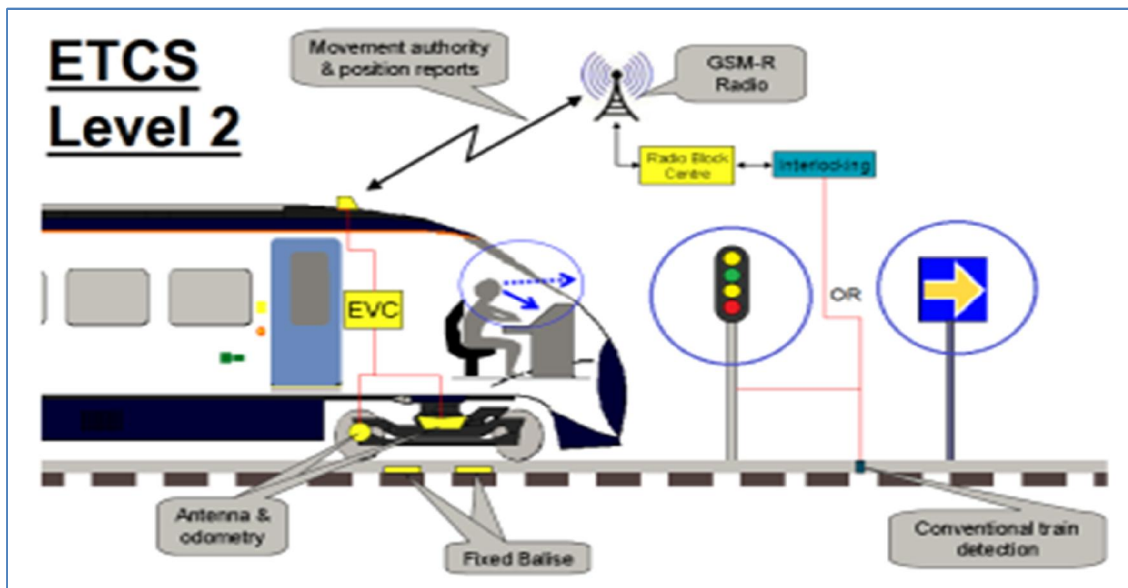
4.4.3 ETCS is not the same as ERTMS. The terms are often confused and used interchangeably. This document primarily concerns/refers to ETCS and the GSM-R element where necessary.

4.4.4 Different levels of ETCS functionality may be implemented: Level National Train Control (NTC), Level 0, Level 1 (L1), L2, and L3. A description of the levels is given in the table below:

ETCS Levels	Level Description
Level NTC	Enables ETCS fitted trains to operate on infrastructure not fitted with ETCS. Safe movement of the train is controlled by the underlying national control systems; in case of UK this will be TPWS and AWS.
Level 0	ETCS fitted trains operating on lines with no ETCS or any other train protection or warning system.
Level 1	Movement authority (e.g. from a conventional line-side signal) is passed to the train via active 'balises' on the track. Generally repeating the indication from the lineside signalling system.
Level 2	Movement authority is passed to train via radio network (GSM-R) from a Radio Block Centre (RBC). Conventional train detection systems are utilised in conjunction with interlocking system to enforce safe train separation.
Level 3	Builds on Level 2, but enforces safe train separation using safety critical data from the train, rather than conventional train detection systems. Level 3 is yet to be fully defined by the European Union Agency for Railways (ERA).



- 4.4.5 The system is available from a number of suppliers and is also used on railways outside the European Union.
- 4.4.6 Continuous ATP is an inherent part of ETCS functionality for Level 2 and above, with Level 1 providing balise based intermittent ATP similar to SELCAB-ATP.
- 4.4.7 Network Rail has an implementation plan for national deployment of ETCS L2. A pilot project has been installed and is in operation on the Cambrian Route in Wales. ETCS



L2 has also been installed on the Thameslink Route in the core section between St Pancras and Blackfriars; this is an ETCS L2 system with lineside signals, and additionally an Automatic Train Operation (ATO) system.

4.4.8 ETCS L2 will ultimately mean that lineside signals (and with future development of ETCS L3, lineside train detection) may be removed.

4.4.9 Under all levels of ETCS train drivers are provided with a target speed and the movement authority distance on a screen in the cab (see Figure 5). The train identifies where it is through a combination of trackside equipment (balises) and on-board sensors (odometry), while instructions from the



control centre are conveyed to the driver through GSM-R. In addition to the information instructed to the driver ETCS will automatically intervene to control the speed of the train in the event that instructions are not being followed.

4.5 ETCS Level 2 Limited Supervision – what is it?

4.5.1 ETCS Level 2 Limited Supervision is a development proposal that, based on the information currently available, aims to deliver a viable, affordable and effective train protection enhancement available for the GB network using some ETCS functionality.

4.5.2 The solution will provide safety improvements and is compatible with a later migration to full ETCS Level 2 with the potential to facilitate some earlier fitment than currently planned.

4.5.3 The system utilises existing components and/or low integrity developments within a structured ETCS requirements suite and therefore has been identified by the supply industry as a low technology risk.

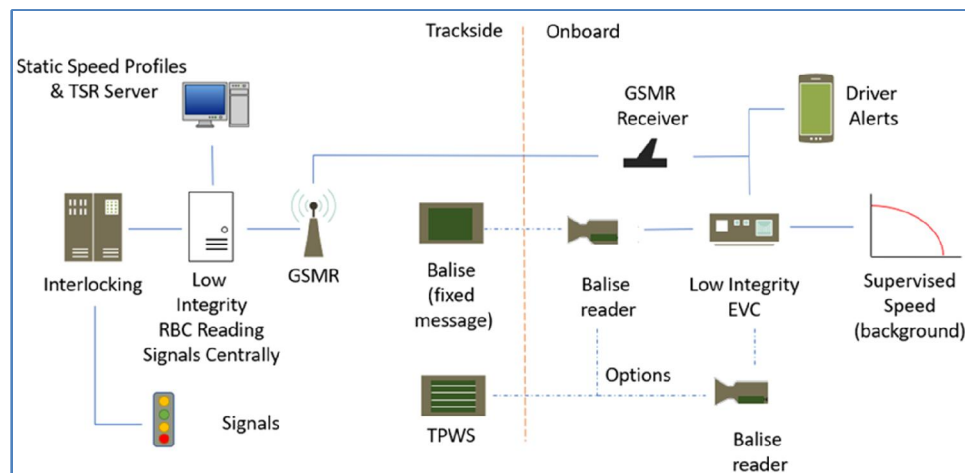


Figure 6

- 4.5.4 Various arrangements of infrastructure and train fitment allow for potential widespread implementation of ETCS Level 2 Limited Supervision which is migratable to ETCS Level 2 Full Supervision because the constituent parts are arranged in a broadly compatible manner with similar interfaces as shown in Figure 6.
- 4.5.5 Application will require several systems development and applications dependent on the existing track and train systems.
- 4.5.6 An ETCS Level 2 Limited Supervision system has not yet been deployed anywhere and is currently developing a Concept Demonstrator and Prototype system to fully define the system and validate the system functionality.
- 4.5.7 The system development is exploring the following elements and interface options to be considered during the system definition and development:
- Low integrity RBC
 - Low integrity EVC
 - Data sniffer or listening device
 - TPWS reading ETCS balise
 - Driver alerts via radio
 - GSMR/GSM transfer of movement authority
 - Nationwide trackside server and virtual balise
 - Learning needs analysis and role profiling to establish training/competence requirements

4.6 ATP/ETCS/TPWS system comparison

- 4.6.1 As part of the previous work on Great Western, a NR peer review compared GW-ATP and TPWS functionality to understand and quantify the differences. The aim was to consider whether enhancing TPWS could produce a comparable level of functional protection to GW-ATP for the required trains. The peer review concluded that certain features of GW-ATP could not be duplicated, but enhancing TPWS would lead to comparable performance levels.
- 4.6.2 Although this work was carried out on GW-ATP, the SELCAB ATP functionality is comparable between the two systems.
- 4.6.3 During the Western Route application of Enhanced TPWS, it was identified that not all Enhanced TPWS functions were practical. However, overall TPWS effectiveness could be maintained by considering the conflict point at a signal rather than overlap, and not fitting extra TPWS to PSRs or Buffer stops.
- 4.6.4 A summary of the comparison of systems is contained in the table below:






Function	ATP	ETCS L2	'Standard' TPWS	'Enhanced' TPWS
Supervision	Continuous - Supervision of driver using "distance to go" calculations, intermittent contact with lineside infrastructure	Continuous - Supervision of driver using "distance to go" calculations. Contact with interlocking via radio	Intermittent - Supervision and contact with lineside infrastructure	Intermittent - Supervision and contact with lineside infrastructure
Transmission failure monitored. (Beacon or radio or loop)	Yes – If an expected transmission is missed. System changes to partial supervision mode and makes an immediate (but recoverable) brake application	Yes – Balise - failures reported on MSS Radio – Service break after thirty seconds	Yes – Loop failure indicated to signaller. For most TPWS failures, signal on approach is held at red	Yes – Loop failure indicated to signaller. For most TPWS failures, signal on approach is held at red
Display to driver	Yes – Provides assistance to driver with cab display and audible warnings	Yes – Provides assistance to driver with cab display and audible warnings	Yes – Notifies driver of brake demand and TPWS isolation/failure only	Yes – Notifies driver of brake demand and TPWS isolation/failure only
Monitors changes in permanent speed restrictions (PSR)	Yes – Changes are displayed to driver. with speed calculated based on braking performance	Yes – Changes are displayed to driver. with speed calculated based on braking performance	Some PSRs – Speed checked on approach to the PSR and only Regulated PSRs	Some PSRs – Speed checked on approach to the PSR and only Regulated PSRs
Monitors adherence to maximum permitted line-speed	Yes	Yes	No	No
Monitors diverging speed at junctions	Yes	Yes	Partial - Regulated PSRs when no restricting junction signal controls are provided. Only at MAF-SD controlled junctions	Partial - Regulated PSRs when no restricting junction signal controls are provided. Only at MAF-SD controlled junctions
Monitors temporary speed restrictions (TSR)	Yes	Yes	Partial - Considered on Regulated TSRs if in place more than 12 months or, less than 12 months on >100mph lines with >200 trains per day	Partial - Considered on Regulated TSRs if in place more than 12 months or, less than 12 months on >100mph lines with >200 trains per day

Function	ATP	ETCS L2	'Standard' TPWS	'Enhanced' TPWS
Stop train if it passes signal at danger	Yes - Within overlap, with release speed calculated based on braking performance and overlap length except where in-fill loop provided	Yes - Within overlap	Some signals - Generally only for signals that provide protection at junctions	Yes - Fit all main signals with TPWS TSS
Prevent train approaching signal faster than braking performance permits	Yes - Using distance to go calculations based on train braking performance	Yes - Using distance to go calculations based on train braking performance	Some signals - If TPWS OSS as fitted. Most signals fitted with TPWS use one or more OSS, designed to stop most trains in SOD	Yes - TPWS OSS as fitted. Signals fitted with one or more OSS, designed to stop as many trains as practical before conflicts.
Monitors approach to buffer stops	Yes - Controls train speed to maximum of 6mph	Yes - Controls train speed to maximum of 6mph	Yes, - Single OSS on approach to buffers. Generally speed checked to be less than 12.5mph	Yes, - Single OSS approach to buffers. Generally speed checked to be less than 12.5mph
Monitor position light moves at reduce speed (e.g. call-on)	Yes	Yes	No	No
Monitors train rolling away	Yes - Monitors correspondence between direction of movement and controller position	Yes - Onboard function	No - Part of Chiltern requirements for LUL operation	No - Part of Chiltern requirements for LUL operation

4.7 Train types & Services

- 4.7.1 CRCL services currently operate a mixture of long distance and commuter passenger services with a mixture of Diesel Multiple Units (DMU) and Locomotive hauled trains.
- 4.7.2 Most of the DMU fleet is fitted with SELCAB ATP but with fleet expansion in the last 9 years some DMUs and locomotive hauled trains have cascaded onto the route. These more recent additions are not fitted with SELCAB ATP.
- 4.7.3 Trains fitted with SELCAB ATP must use it on the route as this provides the greatest level of protection and use TPWS/AWS that is fitted to the infrastructure and used nationally on the mainline network

4.7.4 The following table shows the protection used on each class of train in regular use on the relevant section:





Marylebone to Aynho Junction – Trains			Train Protection Fitted			
Class/Type	Service	Picture	Sets Operated	SELCAB ATP	TPWS	ETCS
Class 68 Locomotive Hauled	Long Distance routes		6 – class 68 (Operating 5 sets of carriages)	N	Mk 4	N
DVT Locomotive Hauled	Long Distance routes		6 - DVT (Operating 5 sets of carriages)	N	Mk1	N
168/0 DMU	Long and Medium Distance routes		5	Y	Mk1	N
168/1 DMU	Long and Medium Distance routes		8	Y	Mk1	N
168/2 DMU	Long and Medium Distance routes		6	Y	Mk1	N

Chiltern Railway ATP Obsolescence Project

Doc Ref: 161667-NWR-APP-SSD-000001

Version No: V1.0

Date: 10th June 2020

Marylebone to Aynho Junction – Trains			Train Protection Fitted			
Class/ Type	Service	Picture	Sets Operated	SELCAB ATP	TPWS	ETCS
168/3 DMU	Long and Medium Distance routes		9	N	Mk4	Y
172/1 DMU	Short and Medium Distance Routes		4	Y	Mk1	Y
165 /0 DMU	Local routes		39	Y	Mk1	N
Freight / Loco	Freight		1-4 Trains per day	N	Y	N

5 Train Protection Exemption

5.1 Why is an exemption required?

- 5.1.1 In 2012, the SELCAB system supplier notified both CRCL and NR that they would no longer be able to provide spares and new SELCAB systems after 31st December 2012. At this point discussions were initiated between the CRCL, NR and the supplier to discuss how to best manage and support the SELCAB system. This resulted in a “last time buy” of spares based on estimated requirements through to 2018.
- 5.1.2 Since 2013 NR and CRCL have regularly met to discuss the future of the SELCAB system. In 2012 it had been identified through risk modelling that increasing TPWS provision presented an option to manage the risk into the future.
- 5.1.3 In 2014 a remit was prepared to independently review options and identify a viable solution to ATP replacement. A viable option would permit the continued operation of CRCL services using SELCAB ATP and maintain the safety, reliability and service requirements for operation.
- 5.1.4 Changes to the law with the introduction of the Railways Interoperability Regulations 2011 that restricted provision of new Train Protection systems led to only 3 potential options for the future:
- Find an alternative supplier to manufacture and supply the SELCAB system.
 - Fit ETCS to the route – ETCS is the only form of ATP that is permitted to be installed on the UK mainline railway.
 - Fit Enhanced TPWS to the existing ATP infrastructure and obtain an Exemption from RSR 1999.
- 5.1.5 The review of viable options included, but was not limited to, consideration of the following areas:
- Supplier staff and equipment availability;
 - Limited delivery experience of ETCS in the UK; and
 - Rolling stock integration.
- 5.1.6 CRCL and NR have continued to work together since April 2018 to further develop the project and are now submitting this RSR1999 Exemption Application to allow it to proceed.

6 Option Development and Selection (Process)

6.1 Governance of Railway Investment Projects (GRIP)

6.1.1 NR commissioned the ATP Obsolescence project in line with NR's Governance of Railway Investment Projects (GRIP), as described in Figure 7 below.

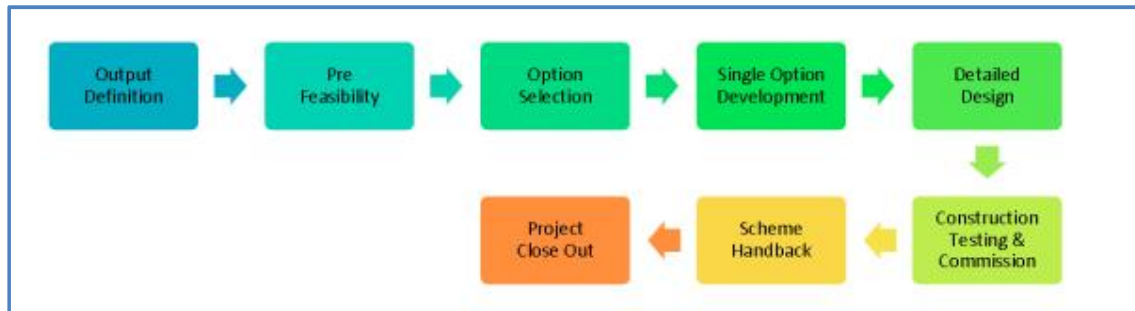


Figure 7

6.1.2 The Project engaged consultant engineers Sotera, NRDD, and Mott MacDonald to support identification and review of options.

6.1.3 GRIP comprises 8 stages, from definition of required outputs through to handover for operational use and close out of the project.

6.1.4 The objectives of GRIP 3 is shown in table below:

GRIP Stage	Stage Aim	Main Output
3	Develops options for addressing constraints. Assesses and selects the most appropriate option that delivers the stakeholders requirements, together with confirmation that the outputs can be economically delivered	Single option determined and stakeholder approval obtained.

6.1.5 Criteria were developed against which the viability of possible options were considered for development:

- System Safety
- Integration Requirements/Risk
- SPAD Risk
- Over-speeding Risk
- Whole Life Cost
- Delivery
- Equipment Development Requirements/Risk
- Approval Requirement/Risk
- Regulation Requirements

- Reliability
- Operational performance
- Maintainability
- Human Factors
- Migration

6.2 Initial Options Development and Review

6.2.1 Working together Mott MacDonald, NR and CRCL, examined options and workshopped possible alternatives to identify viable options and develop a Preliminary System Definition, as represented in figure 8.

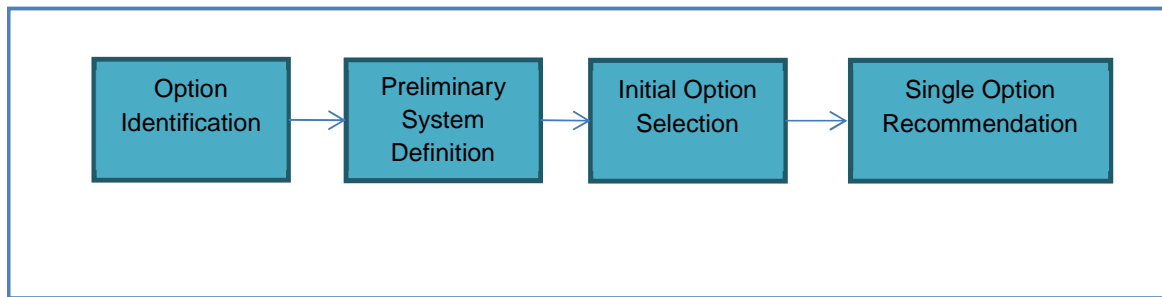


Figure 8

6.2.2 A number of options were agreed for review against the agreed criteria. Options developed were limited to technical solutions for train protection.

6.2.3 Options considered are shown in the table below:

Option	Description	RSR99 Exemption Required
Option 1	Extension of life of the existing SELCAB ATP system	No
Option 2	Deployment of enhanced TPWS provision (including upgrade of train equipment)	Yes
Option 2a	Deployment of TPWS on unfitted signals only	Yes
Option 2b	Deployment of TPWS on unfitted signals and improve fitment of currently fitted signals	Yes
Option 2c	TPWS with ATP equivalent functionality	Yes
Option 3	Accelerated migration to ETCS	No

Initial Options Review

6.2.4 Mott MacDonald prepared an initial review of each of the options identified in 2014. This information was presented to the project for consideration.

- 6.2.5 An option review panel peer reviewed these outputs to determine/recommend options it considered viable for a more detailed analysis.
- 6.2.6 Mott MacDonald report Options for Interim Solution on Chiltern ATP Routes (Reference 2) records the full option selection process and for each option records:
- preliminary system definition;
 - review of option against the selection criteria;
 - outcome of the quorate panel review; and
 - recommendation on options for further detailed review.

Initial Options Selection

- 6.2.7 Options were discounted as part of the initial option selection. A summary of the main justifications for not progressing options is given in the table below:

Option	Description	Summary of why Option Discounted
Option 1	Extension of life of the existing SELCAB ATP system	The obsolescence of equipment, combined with the uncertainty regarding supplier support ultimately renders the pursuit of Option 1 wholly inadvisable so it is therefore not feasible.
Option 3	Accelerated migration to ETCS	Although the overall long term solution for the UK, its early deployment is not feasible within the accelerated timescales

- 6.2.8 Operation with a TPWS options were considered acceptable to progress based on the following key assumptions and factors:
- safety risk level would be comparable to SELCAB-ATP;
 - affordability
 - No technical system development risks (known technology);
 - Integration with future ETCS development (known interface); and
 - Lowest overall delivery risk.
- 6.2.9 This option was taken forward for further detailed analysis, to determine which was considered most appropriate for delivery.
- 6.2.10 Unfortunately, neither CRCL or NR were able to progress this solution except some early infrastructure design studies until the Control Period 6, settlement starting in April 2019 due to limited funding. Control Period 6 specifically provided funds for ATP replacement work to progress.

6.3 Further Option Development and Review

- 6.3.1 Due to delays in funding and following lessons learned from similar RSR99 exemption applied for on Western Route it was considered necessary to review the Initial Option work and consider if additional options were now viable.

6.3.2 Further options considered were not limited to current technical solutions for train protection; also considered solutions in development and also the revisited the ETCS option.

6.3.3 Options developed for risk analysis are shown in the table below:

Option	Description	RSR99 Exemption Required
Baseline	Current lineside TPWS fitment <ul style="list-style-type: none"> • Current ATP fitment • Current mix of Mk1 and Mk4 TPWS fitted to Chiltern cabs. 	No
Option 1	Current lineside TPWS fitment <ul style="list-style-type: none"> • ATP Removed. • Current mix of Mk1 and Mk4 TPWS fitted to Chiltern cabs. 	Yes
Option 2	Enhanced TPWS - Marylebone to Aynho Jnc <ul style="list-style-type: none"> • TPWS at ALL signals • Current mix of Mk1 and Mk4 TPWS fitted to Chiltern cabs 	Yes
Option 3	Enhanced TPWS - Marylebone to Birmingham Moor Street <ul style="list-style-type: none"> • TPWS at ALL signals. • Current mix of Mk1 and Mk4 TPWS fitted to Chiltern cabs 	Yes
Option 4	Current lineside TPWS fitment. <ul style="list-style-type: none"> • ATP Removed • Mk4 TPWS fitted to ALL Chiltern cabs. 	Yes
Option 5	Enhanced TPWS - Marylebone to Aynho Jnc <ul style="list-style-type: none"> • TPWS at ALL signals. • Mk4 TPWS fitted to ALL Chiltern cabs 	Yes
Option 6	Enhanced TPWS - Marylebone to Birmingham Moor Street <ul style="list-style-type: none"> • TPWS at ALL signals. • Mk4 TPWS fitted to Chiltern cabs only (no other TOCs). 	Yes
Option 7	ETCS L2 Limited Supervision - Marylebone and Aynho Jnc <ul style="list-style-type: none"> • Fitted to all signals and cabs 	TBD
Option 8	ETCS Full Supervision - Marylebone and Aynho Jnc <ul style="list-style-type: none"> • Fitted to all signals and cabs 	No
Option 9	ETCS L2 Limited Supervision. <ul style="list-style-type: none"> • Fitted to all Chiltern trains and all signals 	TBD
Option 10	ETCS L2 Limited Supervision - Marylebone and Birmingham Moor Street <ul style="list-style-type: none"> • Fitted to all Chiltern trains and all signals. 	TBD

7 Option Risk Assessment (Overrun/ Safety Justification)

7.1 Introduction

7.1.1 The various functions of TPWS, ETCS and ATP enable them to mitigate SPAD, buffer stop collision and over-speeding risks to varying levels. ETCS has a number of other functions that may permit management of additional risks, but those are still in development as part of the National ETCS Programme.

7.2 Levels of Safety

7.2.1 The Safety Risk Model (SRM) has been developed and published by RSSB to support members' own studies. The primary objectives of the SRM are:

- To provide an estimate of the extent of the current risk on the railway; and
- To provide risk information and risk profiles relating to the railway.

7.2.2 This information is used for risk assessments, appraisals, and to inform decision making throughout the railway industry.

7.2.3 The SRM models hazards that collectively define an overall level of risk on the UK railway. It estimates the total UK network risk and indicates the current level of residual risk (i.e. the level of risk remaining with the current mitigations in place).

7.2.4 The SRM is a key tool used to help support taking safe decisions by:

- Monitoring: are operations safe or might changes be required;
- Analysing and selecting options: what (if anything) should I change and can it be done safely; and
- Making a change: how do I make sure a change is safe?

7.2.5 Data from the SRM was employed in the risk assessment exercise to inform the decisions of the review group (see section 7.4)

7.2.6 Train protection systems mitigate against four main hazardous areas that cause train accidents:

- SPADs, leading to collisions and derailment;
- Over-speeding, leading to derailments;
- Permissive movements, leading to collision; and
- Buffer stop/rollback collisions, leading to derailment.

7.2.7 The usual measure for harm in the mainline rail industry is 'fatality and weighted injury' (FWI) which is a way of measuring the level of harm or risk in a consistent way, by combining the fatalities, major injuries and minor injuries in one unit of measurement. Each injury type is scored in a way that is 'statistically equivalent' to one fatality. The weightings can direct intervention towards those incidents and

accidents that lead to the highest levels of risk without ignoring the types of incident that typically have less severe outcomes.

- 7.2.8 The table below is from the SRM (v8.5.0.2) and gives an overview of the level of residual risk from the SRM that could be further mitigated with train protection systems. These national figures assume that the current TPWS and ATP systems are in place.

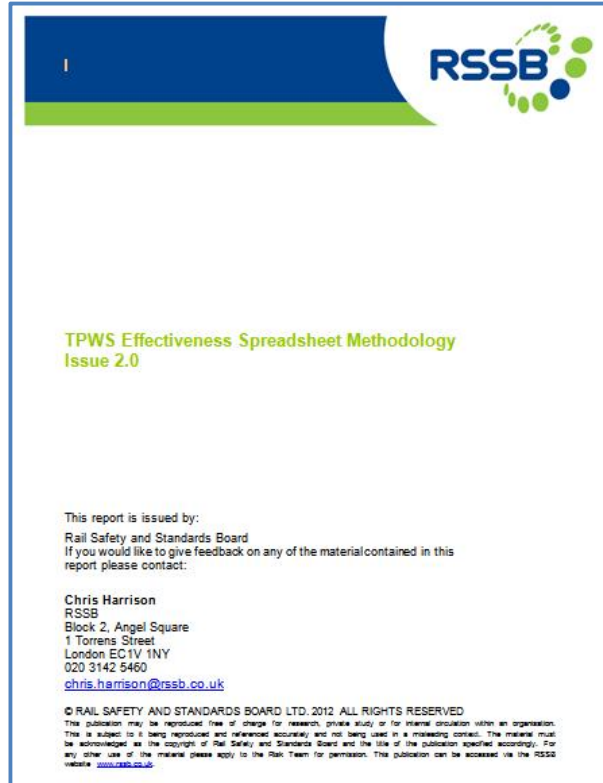
Type of Collision or Derailment Event	Risk (FWI/yr.)
SPAD leading to collisions between trains	0.58
SPAD at Level crossing leading to collision with road vehicle	0.0145
SPAD leading to train derailment at S&C	0.06
Train derailment due to overspeeding	0.0216
Buffer stop collisions	0.165
Permissive working collision	0.073
Total risk	0.993

- 7.2.9 It can be seen that based on SRM data, collision and derailment due to SPADs currently represents a larger share of residual risk than other derailments or buffer stop collision.
- 7.2.10 SRM figures are based on TPWS or ATP currently operating on the network. It is estimated that without train protection figures would increase by a significant amount, and that with ATP fitted nationally total residual risk would be 0.262 FWI/yr., a 74% reduction.
- 7.2.11 Based on the SRM data it can be seen that should a train protection system be changed that SPAD risk is the area that warrants the greatest consideration; this would potentially pose the most significant change in the risk profile.

7.3 TPWS Effectiveness Tool

- 7.3.1 TPWS effectiveness values are a measure of the effectiveness of TPWS at a given signal that considers all trains that use that signal and the likelihood that a train would be stopped before a given collision point. This likelihood is expressed in terms of a percentage and the TPWS effectiveness is defined as the expected number of trains that will stop before the first conflict point in the event of a TPWS trip.

- 7.3.2 RSSB developed the Methodology for TPWS Effectiveness in 2012. This methodology was validated and is contained within an Excel spreadsheet tool.
- 7.3.3 The methodology was originally developed for use when assessing SPAD risk using the Signals Assessment Tool (SAT), and Detailed Assessment (DA) process. These have recently been replaced with the SORAT process (see section 9.3 Further Overrun Risk Assessment) and the methodology has been included within the SORAT software.
- 7.3.4 The methodology employs historical data to determine the probable speed of a train on approach to a signal at danger and thus the effectiveness of the TSS and OSS loops provided.
- 7.3.5 Analysis of data from OSS and TSS trips that resulted in SPADs was used to determine an expected speed distribution and proposition of expected brake activations at TSS and OSS loops.
- 7.3.6 Each class of train expected to use a particular signal under assessment is added to the tool and the overall effectiveness is determined based on the speed distributions calculated, location and number of TSS and OSS loops. Overall effectiveness at a signal is affected by the mix of trains with differing braking performance and/or quantity and position of TPWS loops.
- 7.3.7 The maximum effectiveness of TPWS in reducing the risk from collision and derailment based on this assessment is 95% for Mk1 units. For the Mk3 units the maximum effectiveness is 96.9% and for the Mk4 units the maximum is 98.9%. The values for the Mk3 and Mk4 effectiveness are based upon research conducted for RSSB into reset and continue risk.



7.4 Detailed Risk Analysis of Options

- 7.4.1 How much risk train protection systems are addressing and how effective those systems are at mitigating risk, is addressed in the following section. It should be noted that TPWS is a simpler system than ATP and does not mitigate as much of the risk on a like for like basis. But as TPWS is more widely used, it offers protection to more trains per fitment.

7.4.2 Sotera was commissioned to undertake a detailed risk assessment of the train protection for the area for all the developed options, with current and future planned service levels. The risk assessment focussed on three key areas of risk: train-train collisions from SPADs, derailments from overspeeding, and buffer collisions. These were the hazardous events significantly affected by amending train protection.

Service and Passenger Levels

7.4.3 Current and future service levels were modelled to give a comparison of level risk for current and expected future timetables. Figure 9 below shows the baseline service pattern of CRCL.

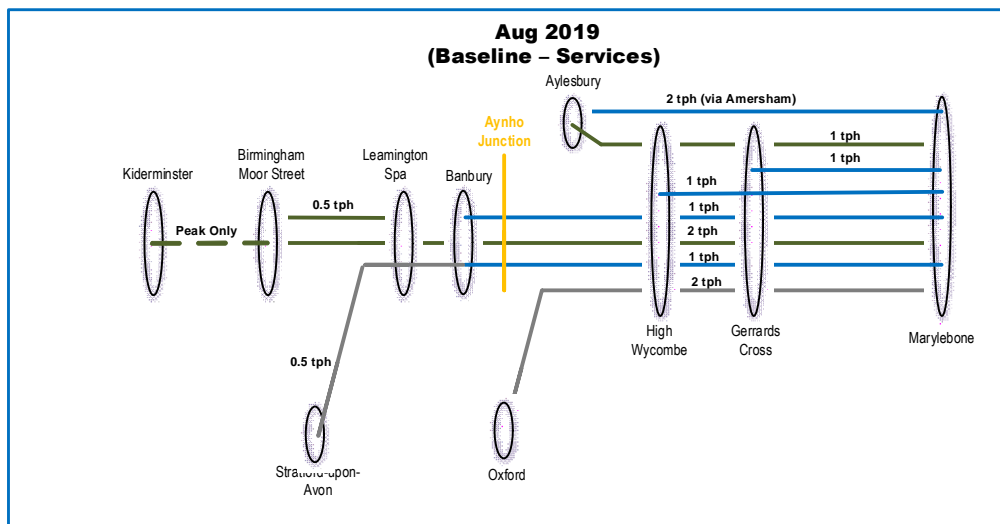


Figure 9

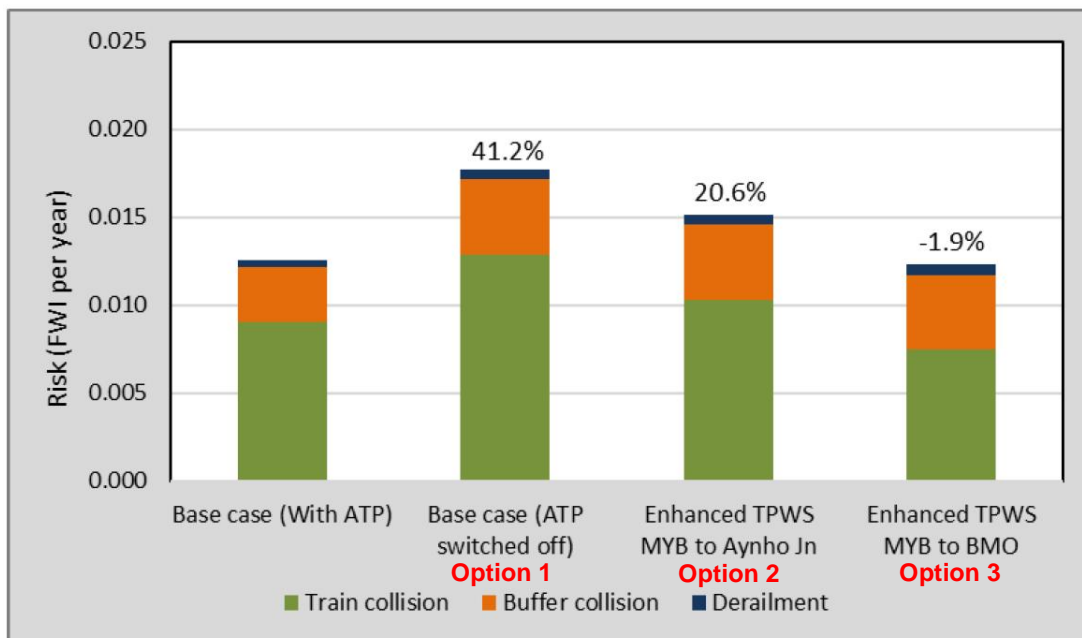
7.4.4 NR and CRCL together determined three potential future service patterns/timetables for 2021, 2023 and 2026 based on known plans for the Chiltern route. These service patterns are summarised in table below termed SP19, SP21, S23 and SP26.

Service Pattern	Description
SP19	Current level of passenger and freight services See Figure 9 above
SP21	Estimated level of train service in 2021 . As per SL19 with the addition of HS2 construction traffic. Growth in passenger numbers is assumed to be 2.5% per year
SP23	Estimated level of train service in 2023 As per SL21, with the addition of East West Rail Phase 2 services Oxford to Cambridge via Bicester and Milton Keynes to Aylesbury. Growth in passenger numbers is assumed to be 2.5% per year.
SP26	Estimated level of train service in 2026 As per SL23. Growth in passenger numbers is assumed to be 2.5% per year

Infrastructure Options comparison

7.4.5 Analyses of the differences between the infrastructure options with ATP switched off was compared for all the current timetable is illustrated below in (Figure 10).

7.4.6 More detail can be found in the Sotera Report - Risk Assessment of the Chiltern Train Protection Strategy (Reference 3).



Options 1 to 3 - Figure 10

7.4.7 Of all the options, overall, Option 3 presents the lowest risk. Option 3 is as effective as an ATP system on the CRCL services, but extends Enhanced TPWS to Birmingham Moor Street (BMO) and would give risk reduction benefits to other operators in the area from Aynho Junction to Birmingham Moor Street.

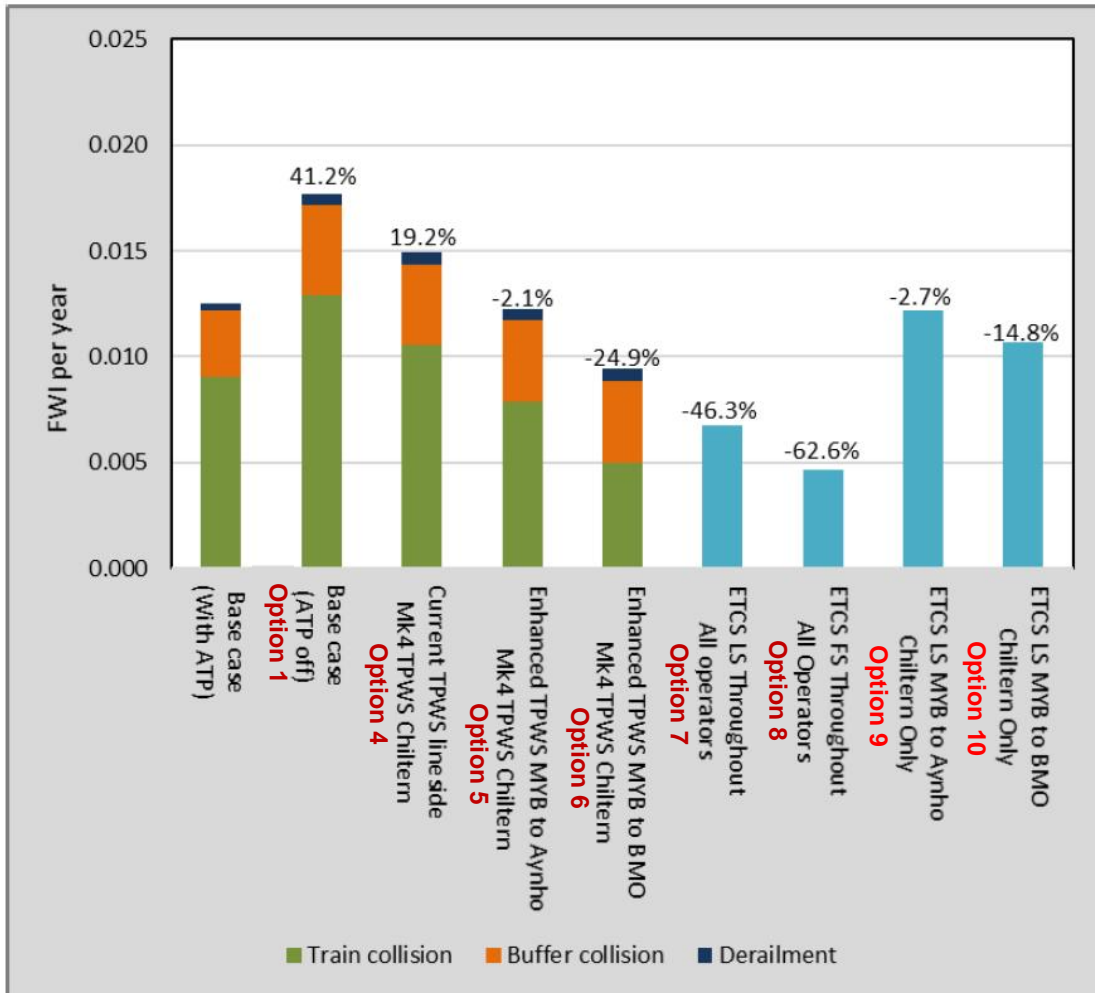
7.4.8 Comparison of individual changes between options are explained as follows:

- Collision risk shows significant change, when ATP is switched off, but is significantly reduced by provision of Enhanced TPWS and reduced further if the geographic area of Enhanced TPWS is increased;
- Buffer collision risk is significantly changed, when ATP is switched off, and is not mitigated by Enhanced TPWS; and
- Derailment risk from overspeeding makes only a small contribution to overall risk, but also increases with ATP switched off.

Infrastructure and Train Upgrade Options comparison

7.4.9 Analyses of the differences between the options which include both infrastructure and train upgrades with ATP switched off was compared for all the current timetable and is illustrated below in (Figure 11).

7.4.10 More detail can be found in the Sotera Report - Risk Assessment of the CRCL Train Protection Strategy (Reference 3).



Options 4 to 10 - Figure 11

7.4.11 Due to the assumption made on the ETCS Options 7, 8, 9 and 10 it was not possible to evaluate the difference in risk type.

7.4.12 Option 1 (ATP off) is shown as a reference case, to allow comparison of risk if no works were carried out.

7.4.13 Of all the options, overall, Option 8 as expected presents the lowest risk, this is as an ATP system in operation on the entire area. This is the long term strategy for the route and National network. Option 7 also would present a significant safety improvement but as explained in section 6.2 these are currently not reasonably practicable to implement.

7.4.14 It can be seen from Option 4 that TPWS onboard upgrade to Mk4 alone gives a significant improvement compared to the Base case with existing onboard TPWS. This 22% improvement is due to the mitigation being applied to all CRCL operations.

7.4.15 Option 5 shows that a combination of TPWS onboard and enhancement in TPWS at signal in the current ATP area would to present a similar level of risk to the current ATP operation.

7.4.16 Option 6 shows that significant improvement in safety as enhanced TPWS protection is applied over a much wider area, but the cost to implement this is also significantly higher.

7.4.17 No option gives a positive cost benefit ratio due mainly to the small risk being managed by the train protection system. Table below shows cost benefit ratio for options that have a cost estimate.

Option	Description	Cost Benefit Ratio
Option 3	Enhanced TPWS - Marylebone to Birmingham Moor Street <ul style="list-style-type: none"> TPWS at ALL signals. Current mix of Mk1 and Mk4 TPWS fitted to Chiltern cabs 	0.008
Option 4	Current lineside TPWS fitment. <ul style="list-style-type: none"> ATP Removed Mk4 TPWS fitted to ALL Chiltern cabs. 	0.008
Option 5	Enhanced TPWS - Marylebone to Aynho Jnc <ul style="list-style-type: none"> TPWS at ALL signals. Mk4 TPWS fitted to ALL Chiltern cabs 	0.012
Option 6	Enhanced TPWS - Marylebone to Birmingham Moor Street <ul style="list-style-type: none"> TPWS at ALL signals. Mk4 TPWS fitted to Chiltern cabs only (no other TOCs). 	0.011

Timetable comparison

7.4.18 Analyses of the differences in timetables with and without ATP switched off was compared for current and future expected timetable is illustrated below in (Figure 12).

7.4.19 More detail can be found in the Sotera Report - Risk Assessment of the Chiltern Train Protection Strategy (Reference 3).

7.4.20 As expected, risk is expected to rise due to the increase in passengers and services introduced to the route.

7.4.21 This increase in risk is approximately 5% per year, with most of this increase attributed to Train Collision.

7.4.22 It can be seen by the final bar in Figure 12 that with the implementation of Enhanced TPWS and Mk4 onboard, this increase risk is expected to be reduced by 12%. This is due to the new services expected to operate with Mk4 TPWS, so greater improvement than just maintaining from Enhanced TPWS.

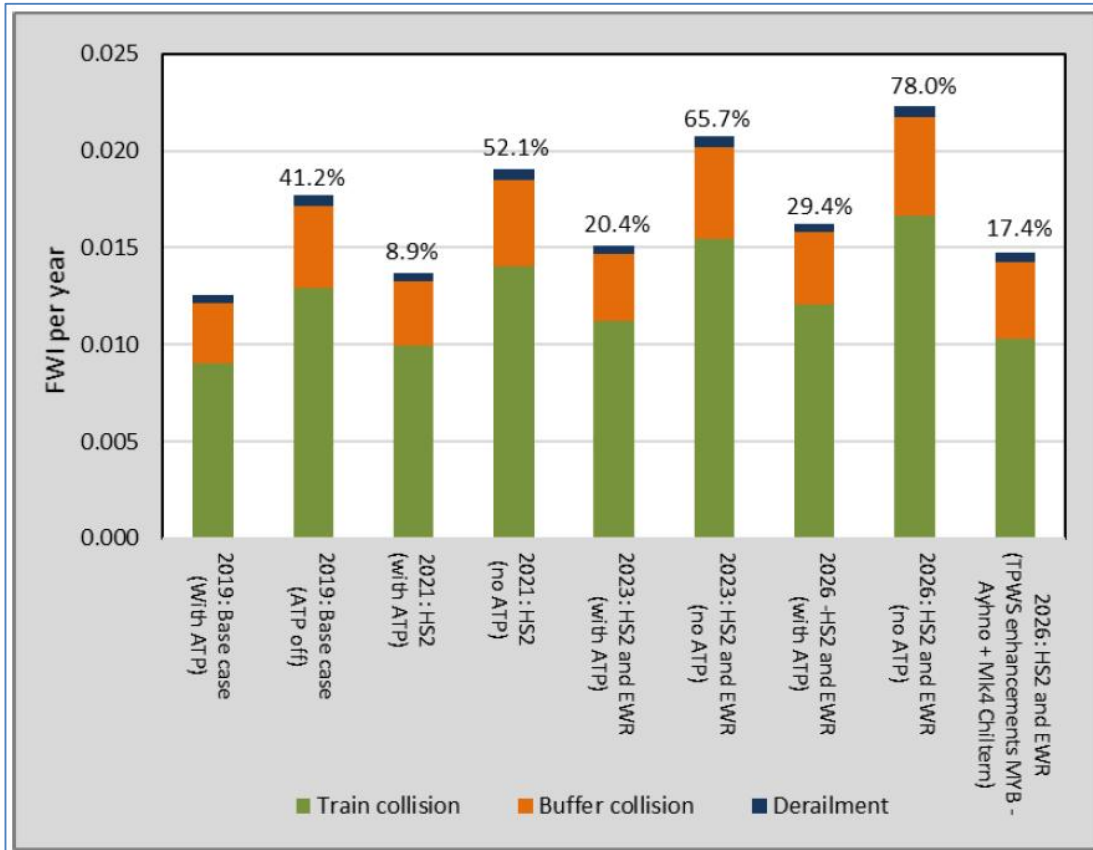


Figure 12

7.4.23 An important assumption underpinning the assessment is that the lower number of train services does not give rise to a higher level of passenger loading on trains, i.e., it is assumed that overall patronage increases and decreases linearly with service levels.

8 Final Option Selection

8.1 Detailed Options Selection and Hazard Identification (HAZID)

- 8.1.1 Following the detailed risk assessment, all options were subject to further detailed assessment to determine the differences in risk between them and further assess likely delivery scenarios.
- 8.1.2 This review considered the Risk Assessment work and additionally charts provided which indicated how the train accident risk would be expected to change based on the four defined time tables and expected delivery of Options.
- 8.1.3 NR, CRCL, Sotera also developed a set of other criteria not quantified by the Sotera assessment that each of the options would be reviewed against.
- 8.1.4 Additional criteria and risks reviewed as part of based Option selection were:
- Safety Performance - train accidents
 - a) Final (2026+)
 - b) Interim
 - c) Further mitigations
 - Safety Performance – other
 - Operational Impact
 - a) Normal
 - b) Degraded/emergency
 - Cost
 - a) Capital
 - b) Ongoing
 - Deliverability/uncertainty
 - a) Technical feasibility
 - b) Delivery within timescales
 - c) Maintainability
 - Impact on other parties (e.g. TOCs)
 - Alignment with business objectives
- 8.1.5 More detail can be found in the Sotera Report - Option selection report for the Chiltern Train Protection Strategy (Reference 1)

8.2 Selected option

8.2.1 An Option Selection meeting was held on the 31st January 2020 to consider options, records of the meeting are contained in Sotera report: Option Selection report for the Chiltern Train Protection Strategy (Reference 1).

8.2.2 After running through the assessment criteria, the selected option was Option 5 based on the following reasons/ rationale:

- Safety:** Overall, this option provides a level of safety risk that is slightly improved compared to the current level with ATP fully operational by 2023 (See figure 13). This is because all stock operating in the Marylebone to Aynho Junction would benefit from the Enhanced lineside TPWS (not all trains operate under ATP in the area). Furthermore, the benefit of the Mk4 TPWS units providing protection against 'reset and continue' SPADs and in-service monitoring would also apply to CRCL services north and west of Aynho junction.

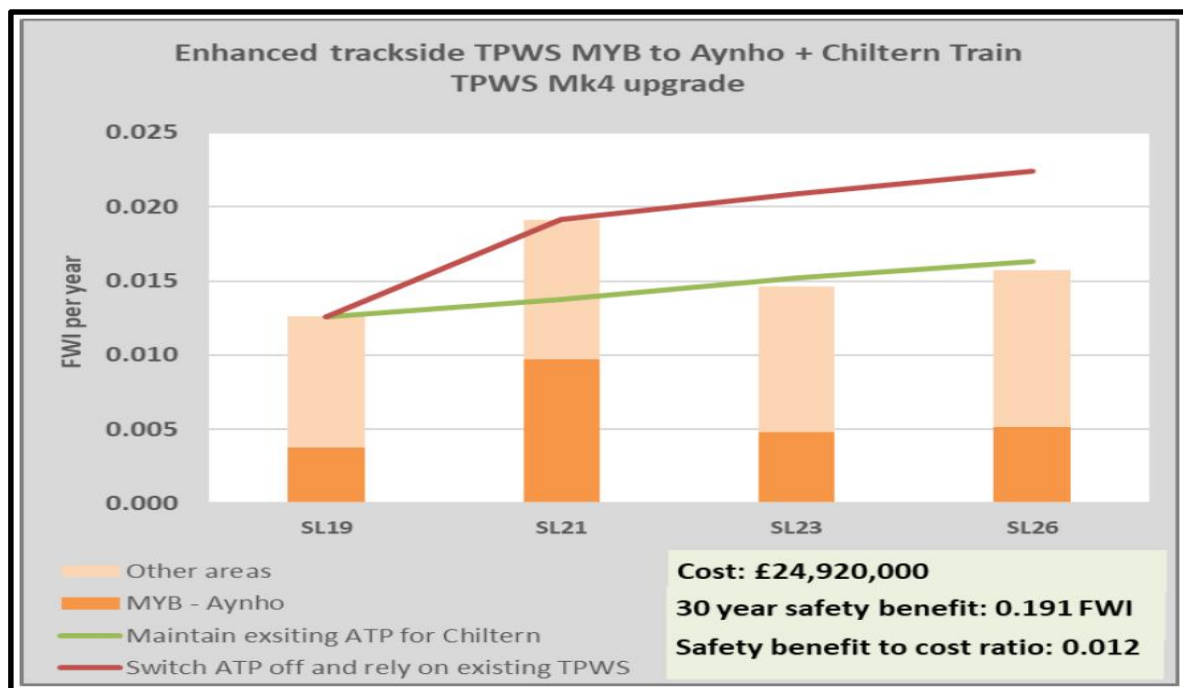


Figure 13

- Operational performance:** Operating with ATP switched-off would result in a modest operational performance improvement between Marylebone and Aynho Junction due to eliminating ATP failures. However, there may be additional delays due to failures and activations resulting from the additional TPWS fitment. Overall, the level of failures is considered to be lower with TPWS as the two systems have a similar service affecting failure rate per installation, but additional TPWS would not be provided at all signals

- **Cost:** The capital cost of this option is approximately £25m including trackside and trainborne upgrades. This is within the CP6 settlement funding.
- **Deliverability and uncertainty:** This option uses existing technology and is therefore relatively deliverable and is among the least uncertain options. One area of uncertainty is the time required to upgrade the train cabs to the Mk 4 units, for which there is limited experience within the industry. The upgrade requires significant rewiring as well as new OTDR units. In order to manage the loss of stock while units are being upgraded, a rolling programme of cab upgrades would be adopted, which could be achieved in the period between 2021 and the mid of 2024. A similar timeframe would be required for the lineside fitment but would be expected to be complete by end 2023.
- **Alignment with business objectives:** The option would be compatible with the industry's migration strategy to eventually transition from a railway protection by TPWS to one protected with ETCS.

8.2.3 The assessment concluded that it was only Option 5 that met the following criteria:

- Maintaining or reducing the risk for the route that is currently protected by ATP between Marylebone and Aynho junction.
- Maintaining or reducing the risk for the entirety of the routes over which CRCL operates.
- Can be delivered with reasonable certainty by the end of 2023 for lineside and mid 2024 for trainborne, there is likely to be significant degradation of the existing ATP system during this period.
- Enables a migration that should not detrimentally impact CRCL, or other operators services.
- Aligns with the industry's strategy to transition from a railway protected with TPWS to one protected by ETCS.
- It has a relatively favourable benefit to cost ratio (note the ratio is 0.012, but this is a higher ratio than other deliverable options).

9 Safety Assurance Process

9.1 Introduction

- 9.1.1 NR's Health and Safety Management System (H&SMS) describes the framework and arrangements in place to deliver the company's health and safety objectives.
- 9.1.2 Safety Assurance will be achieved by application of the CSM-RA, and production of a Safety Assessment Report by an independent assessment body. Further information can be found in ORR document - ORR document - Guidance on the application of Commission Regulation (EU) 402/2013 – September 2018¹
- 9.1.3 In line with accepted NR processes, as the design is developed further the project will go through all of the detail to ensure the outcomes meet or exceed expectations. A final Safety Justification report will then be produced. The final Safety Justification report will be reviewed and accepted (as appropriate) by a NR System Review Panel (SRP). This process will provide final assurance of achievement of the objectives.
- 9.1.4 Before acceptance by SRP the Safety Justification will be reviewed by an Independent Safety Assessor (ISA), whose review shall cover the following topics:
- Scope;
 - Hazards identified;
 - Assessment of risks;
 - Control measures during the change period and afterwards;
 - Residual risks; and
 - Arrangements for monitoring and review.

9.2 Common Safety Method for Risk evaluation and Assessment (CSM-RA)

- 9.2.1 CSM-RA is a framework that describes the common mandatory European risk management process for the rail industry. Further information can be found in ORR document - *Guidance on the application of Commission Regulation (EU) 402/2013 – September 2018*.
- 9.2.2 The joint GRIP 3 review of the ATP Obsolescence Project has applied CSM-RA methodology to the initial option selection stages and has undertaken to develop a preliminary system definition for each option. This preliminary system definition was used to assist in analysing what risks were being changed by options and the level of impact on safety that could be expected from each option being proposed, it has also assisted in identify the significance of the change proposed.
- 9.2.3 Each change has been subject to an initial significance assessment in line with CSM-RA requirement, and recorded in the table below

¹ [Guidance on the application of Commission Regulation \(EU\) 402/2013 – September 2018](#)

Change Description	Significant
Delivery and operation of Enhanced TPWS (Lineside).	No (NR AsBo) (Reference 7)
Delivery and operation of Enhanced TPWS (onboard) and removal of SELCAB ATP from use.	Yes (Chiltern AsBo) (Reference 6)

9.2.4 In effect, this analysis of what was being changed and a preliminary risk assessment of that change constituted a preliminary risk assessment of that option. This risk assessment was supported by a detailed risk assessment, on risks controlled by train protection.

9.2.5 This process is in line with ORR guidance on the application of CSM-RA.

9.3 Further Overrun Risk Assessment

9.3.1 Assessments carried out to date have given an indicative effectiveness for Enhanced TPWS at mitigating signal overrun risk. These results have shown that when further risk assessment is carried out, signal overrun risk for an Enhanced TPWS solution would be similar to, and for some signals greater than, that offered by ATP or ETCS alone.

9.3.2 NR is required to carry out a more detailed Signal Overrun Risk Assessment Process in line with CSM-RA, Railway Industry Standards and its own company standards when infrastructure, train service or train types change.

9.3.3 Signal overrun risk assessment processes have been established over many years and developed from the requirements of the now withdrawn Railway Group Standard, GI/RT7006 - Prevention and Mitigation of Overruns – Risk Assessment.

9.3.4 NR's company standards now cover the process in more detail, and the basis of this process has recently been published by RSSB as a Railway Industry Standard, RIS-0386-CCS, Rail Industry Standard on Signal Overrun Risk Evaluation and Assessment²

9.3.5 To support the Signal Overrun Assessment process, NR has developed the Signal Overrun Assessment Tool (SORAT). SORAT is a software tool that calculates signal overrun risk, on a signal by signal basis, and stores the results on a national database. Calculations are based on complex algorithms and historical data on the likelihood and consequences of a signal being passed at danger.

² <https://www.rssb.co.uk/rgs/standards/RIS-0386-CCS%20Iss%201.pdf>

9.3.6 SORAT requires detailed information about the local layout, trains used and timetable associated with each signal. This information is used to determine a Risk Score per signal using the Fatality Weighted Index (FWI) as shown in Figure 14 below.

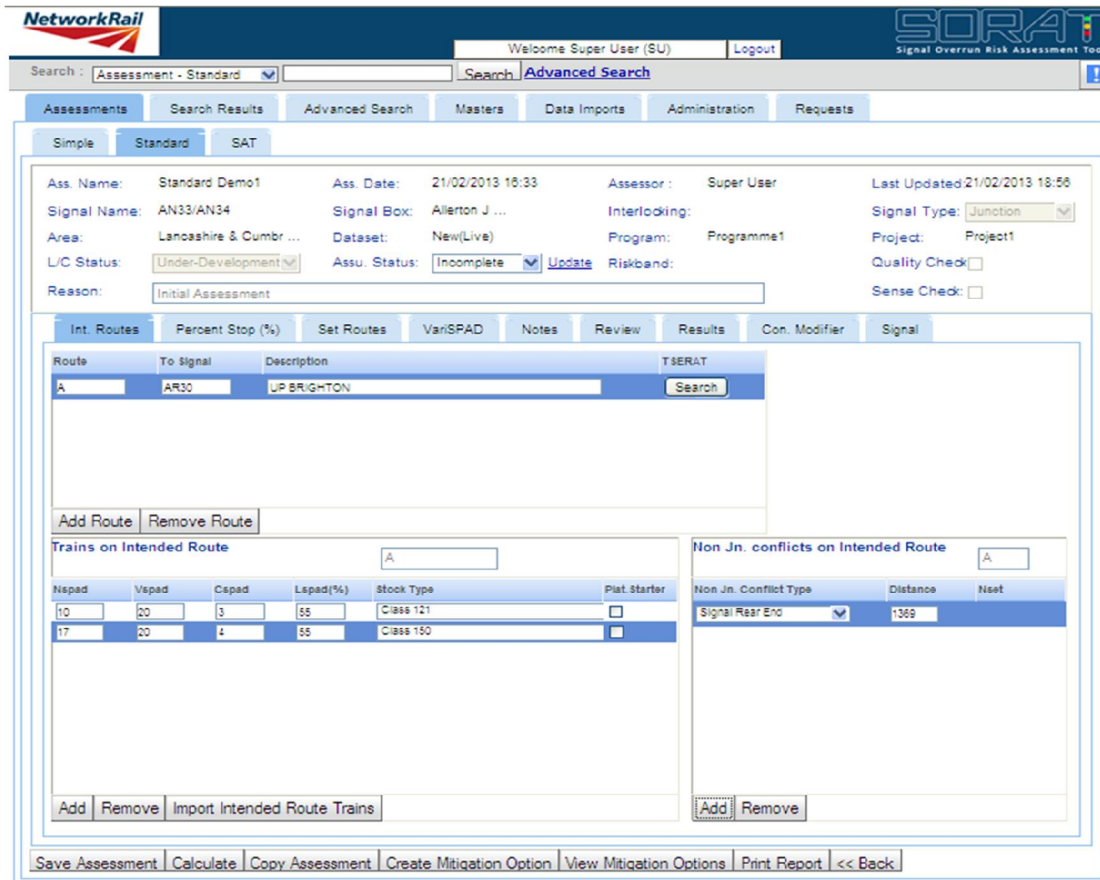


Figure 14

9.3.7 This enables NR to rank each signal based on risk score. SORAT is then used for a more detailed assessment, in consultation with the train operators, for those signals that present the highest risk. It can then be determined whether the proposed mitigations against overrun risk at that signal are suitable and sufficient. This review (known as a “VariSPAD”) considers the level of train protection provided on each signal and other risk factors that may increase or decrease SPAD risk (Figure 15)

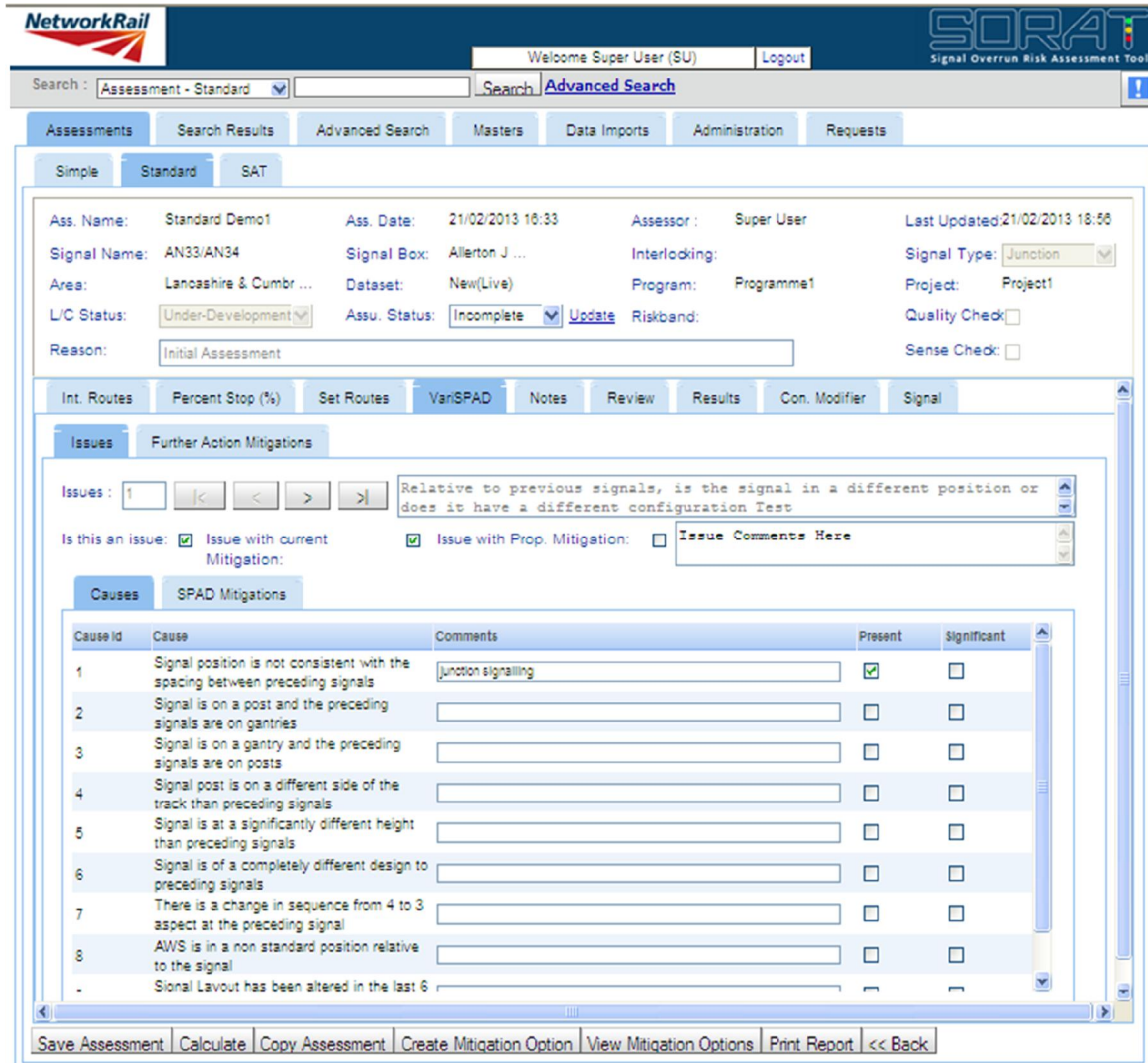


Figure 15

9.3.8 SORAT has built in risk algorithms similar to those used to estimate the train protection effectiveness as part of the GRIP 3 option selection process (see section 7.3 TPWS Effectiveness Tool). In this instance, however, the algorithm has the benefit of the final agreed train quantities and TPWS/ATP arrangements.

9.3.9 Results are produced, and SORAT then stores all commissioned signals' records. These records can then be reviewed and updated if changes occur to the signal or its use, for example layout change, train type change or timetable variations (Figure 16).

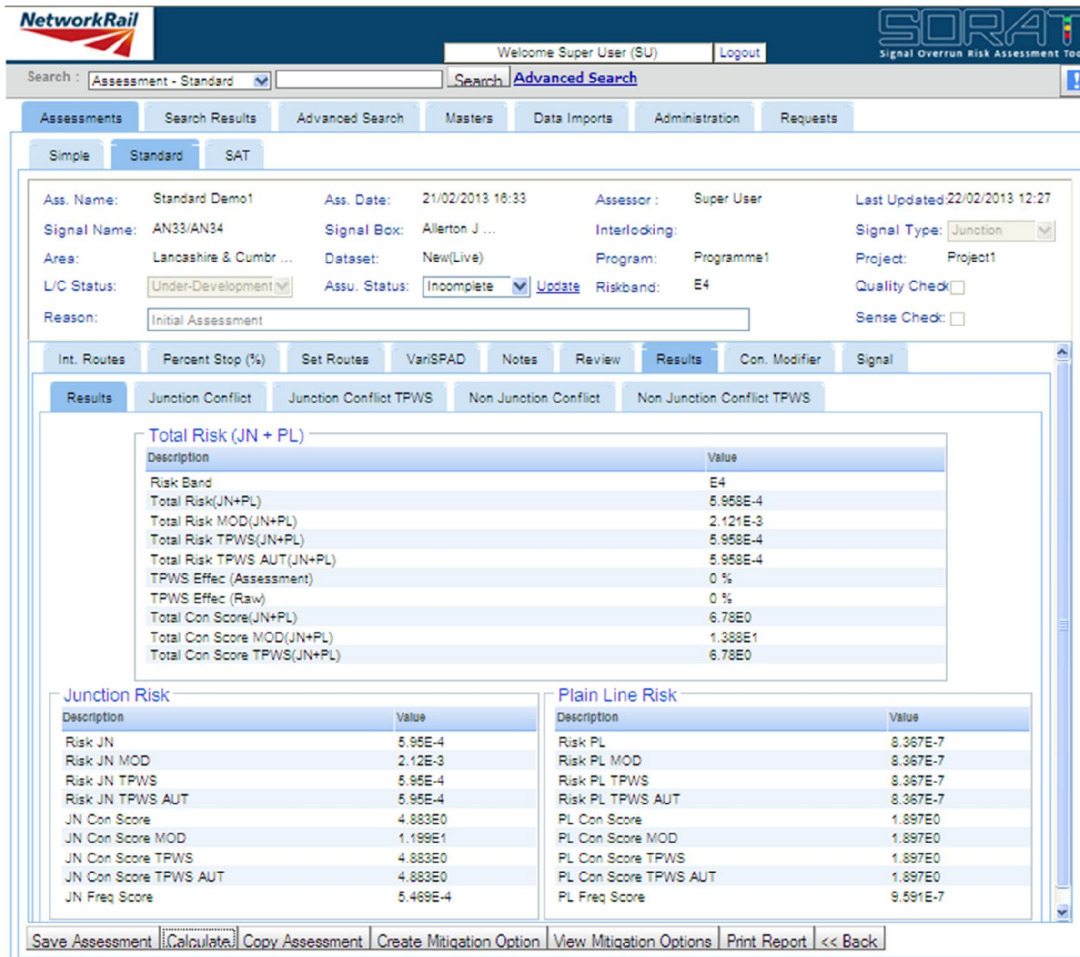


Figure 16

9.3.10 Each signal will need to be taken through the SORAT process, and only if the levels of risk are determined to be (ALARP) by Network Rail and TOC/FOC users will the signal and its train protection be deemed acceptable without additional mitigations.

9.4 Operational Safety Plan

9.4.1 NR and CRCL have developed and agreed an Operational Safety Plan to jointly agree how train protection risk will be managed on the Chiltern Route during the period of the exemption.

9.4.2 NR and CRCL have agreed following management actions are required: -

- Annual Review of the train protection risk.
- Criteria for deterring when to remove SELCAB ATP from use .

10 Conclusion

- 10.1. The strategy of increasing use of TPWS for train protection has been supported for several years and has been a key element of rail industry safety policy.
- 10.2. Following extensive review, evaluation and quantification of the levels of safety offered by Enhanced TPWS it has been found to offer a similar protection level to the current SELCAB-ATP/TPWS for the proposed mix of services and rolling stock.
- 10.3. We conclude that:
 - The safety benefits from using TPWS to mitigate Signal Passed at Danger risks are substantial;
 - TPWS is, within its design limitations, an effective system for mitigating SPAD risk;
 - The provision and maintenance of additional TPWS equipment will not expose the workforce to significant additional risks; and
 - TPWS is not considered a train protection system under RSR99 where it is reasonably practicable to install an Automatic Train Protection system, such as that intended for ETCS implementation. On this basis, it is necessary for us to obtain an exemption from this requirement in order to continue use of Enhanced TPWS as our fall-back train protection solution.
- 10.4. Enhanced TPWS proposals are demonstrably safe, fit for purpose and represent what is considered as the best option until industry plans for ETCS operation are determined.
- 10.5. A wide range of potential future train protection strategies have been analysed in detail to determine the optimum strategy to address the issue of obsolescence of the existing ATP system for the Chiltern route. These options were appraised using detailed risk assessment and application of agreed option selection criteria. The assessment concluded that there is only one option that meets the following criteria:
 - Maintaining or reducing the risk for the route that is currently protected by ATP between Marylebone and Aynho junction.
 - Maintaining or reducing the risk for the entirety of the routes over which CRCL operates.
 - Can be delivered with reasonable certainty by the end of 2023 for lineside and mid 2024 for trainborne, there is likely to be significant degradation of the existing ATP system during this period.
 - Enables a migration that should not detrimentally impact CRCL, or other operators services.
 - Fits with NR's strategy to transition from a railway protected with TPWS to one protected by ETCS.

- Has a relatively favourable benefit to cost ratio.

10.6. This is Option 5, which includes:

- The provision of Enhanced lineside TPWS between Marylebone and Aynho junction to latest standards.
- Upgrading the CRCL cab TPWS units to Mk4, which have protection against TPWS 'reset and continue' events following SPADs as well as continuous health monitoring. This element of the safety benefit pervades across all CRCL services and over all the main line infrastructure they operated.
- Providing rollback protection for cabs that operate over London Underground infrastructure.

10.7. Therefore Option 5 is the Selected Option for which this exemption application is made.

10.8. NR and CRCL intend to start to remove ATP and operate with the Enhanced TPWS option from some time in 2023 and this report provides justification for an exemption from the requirement under Regulation 3 of the Railway Safety Regulations (1999); that a train should be fitted with a train protection system (as defined by Regulation 2).

10.9. The operation of the Chiltern route during the exemption period will be in accordance with the Chiltern Route Train Protection - Railway Safety Regulations 1999 Exemption Operational Safety Plan – R362 (Reference 5).

11 Stakeholder Engagement/Consultation

- 11.1. A number of stakeholders have been engaged / consulted, and others will be subsequently informed.
- 11.2. The following stakeholders have been a key part of the exemption development and have provided letters in support of the exemption request:
- The Chiltern Railway Company Limited (“Chiltern Railways”).(Reference 8)
- 11.3. Following stakeholders have been identified and engaged in preparation of this exemption application:
- Department for Transport (DfT)
 - Office of Road & Rail (ORR)
 - Railway Safety & Standards Board (RSSB)
 - Trade Unions (ASLEF, RMT, UNITE)
 - Train Operating Companies (TOCs), including Trade Unions:
 - Transport for London /London Underground
 - Freight Operating Companies (FOCs)
 - Train Owners:
 - Angel Trains
 - Eversholt Rail Group
 - Porterbrook Leasing
 - Direct Rail Services
- 11.4. The following Network Rail internal stakeholders have been identified and engagement as required
- Regional and Route Directors
 - Regional DEAM Team
 - Route Sponsor Team
 - System Operator
 - Route Operations & Maintenance.
 - Network Rail Capital Delivery
 - Professional Head of Signalling.
 - Digital Railway Directorate (DRD).

12 References

Reference	Title
1	Option selection report for the Chiltern Train Protection Strategy, J2044, Revision 2, Sotera Risk Solutions, February 2020.
2.	Options for Interim Solution on Chiltern ATP Routes – Options Review Report, 3892299/01, March 2015.
3.	Risk Assessment of the Chiltern Train Protection Strategy, J2044, Rev 03, 17 th January 2020.
4.	SELCAB ATP Short Term RSR 1999 Exemption Summary Report (R363)
5.	Chiltern Route Train Protection Railway Safety Regulations 1999 Exemption, Operational Safety Plan, Draft Report (R362), Chiltern Railways, April 2020
6.	SELCAB ATP Removal: Assessment of Verification Route, Report (R351), Chiltern Railways, January 2020.
7	Chiltern ATP Significance Test v1 – 05 May 2020 - Draft
8	Chiltern Railways Letter of Support – 12 th June 2020