Options for Interim Solution on Chiltern ATP Routes

Options Review Report

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Table 1.1: Table of Acronyms

Acronym	Description
AsBo	Assessment Body
ASLEF	Associated Society of Locomotive Engineers and Fireman
ATO	Automatic Train Operation
ATP	Automatic Train Protection
APiS	Authorisation for Placing into Service
CCO	Control Command and Signalling (On-board) Subsystem
CCT	Control Command and Signalling (Trackside) Subsystem
CSM	Common Safety Method
DeBo	Designated Body
DIU	Driver Interface Unit
DVT	Driving Van Trailer
EPROM	Electronic Programme Read Only Memory
ERA	European Railway Agency
ETCS	European Train Control System
ETM	European Transmission Module
FOC	Freight Operating Company
FWI	Fatality and Weight Injury
FIC	First in Class
GSM-R	Global System Mobile Communications Railways
GWML	Great Western Mainline
H&SMS	Health and Safety Management System
HF	Human Factors
HMRI	Her Majesty's Railway Inspectorate
IM	Infrastructure Maintenance
IPR	Intellectual Property Rights
LED	Light Emitting Diode
LEU	Loop Electronic Unit
LRU	Loop Reading Unit
LUL	London Underground Limited
MA	Movement Authority
NR	Network Rail
NRAP	Network Rail Approvals Panel
ORR	Office of Rail Regulation
PAN	Project Advice Note
PSR	Permanent Speed Restriction
REA	Risk Evaluation and Assessment
ROGS	Railways and Other Guided Transport Systems (Safety) Regulations

Acronym	Description
RSR 99	Railway Safety Regulations 1999
RU	Railway Undertakings
SG	Steering Group
SIL	Safety Integrity Level
SMS	Safety Management System
SORAT	Signal Overrun Risk Assessment Tool
SPAD	Signal Passed at Danger
SSI	Solid State Interlocking
STM	Specific Transmission Module
TEN	Trans European Network
TOC	Train Operating Company
TPWS	Train Protection Warning System
TSI	Technical Specification for Interoperability
TSR	Temporary Speed Restriction
TU	Transport Undertaking
V&V	Verification and Validation
VOBC	Vehicle On Board Controller

Contents

Executive Summary

Network Rail commissioned Mott MacDonald to complete a study into the potential solutions for an interim train protection system between 2018 and 2028, when the European Train Control System (ETCS) Level 2 is due to be implemented. The present Automatic Train Protection (ATP) installation is life expired and experiencing Reliability, Availability, Maintainability and Safety (RAMS) issues.

Three high level options were selected by the Chiltern ATP Steering Group (SG) for consideration by this report:

Option 1:	Extension of life of the existing ATP system
Option 2:	Deployment of enhanced TPWS provision (including upgrade of train equipment)
Option 2a:	Deployment on unfitted signals only
Option 2b:	Deployment on unfitted signals and re-fitment of currently fitted signals
Option 2c:	TPWS with ATP equivalent functionality
Option 3:	Accelerated migration to ETCS

This report investigates and analyses the three options (and sub-options), and makes recommendations as to which makes the most viable solution as an interim train protection system from 2018 to 2028.

The report was compiled gathering a wide range of information from multiple primary and secondary sources and independent studies, contributions from numerous Mott MacDonald staff from multiple disciplines, and many staff from stakeholder companies. The evidence is used assessing the three options against 14 key criterias specified by the Chiltern ATP SG. The following criteria are used in this report to analyse and compare the three options:

- 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

From the investigations, Option 2 was found to be the most viable option given; the current National Rail programme constraints; the deliverability of the system (within the specified timescales); the affordability and the fundamental fact that it will expeditiously bring an overall safety improvement when compared to the current situation. Although the selection of Option 2 will necessarily mandate early engagement with the regulators this would most certainly be the case for all of the three options under scrutiny.

The selection of Option 2 as the most viable option also aids migration to ETCS and will thus facilitate a much smoother transition to the programmed installation of the new ETCS train protection system, as Chiltern will effectively require the same upgrade as the majority of other lines in the UK (from TPWS to ETCS Level 2). Given the current programme constraints, the overall cost of selecting Option 2 will be far less than accelerating the deployment of ETCS, as defined in Option 3 (even though Option 2 also includes an upgrade of trainborne equipment), which would encompass not utilising the existing assets to the end of their whole life as defined in the current business case.

Despite TPWS's limitations with respect to protecting trains with braking capabilities below 9%g, Option 2 is estimated to offer a reduction in risk over the whole Chiltern railway of 9% when compared with the current provisions (Sotera, 2012). This decrease in risk is a result of the increase in protection of non-ATP fitted vehicles that currently suffer from increased risk due to the partial TPWS coverage of the current installation.

Notwithstanding the above recommendation the client must be diligent in understanding that a detailed risk-based safety assessment including (but not limited to) SORAT assessments of every signal on the route must be carried out to determine if a viable Safety Case can be produced for Option 2. It should also be noted that Option 2 results in a significant change in the current system's functionality, including the loss of roll-back protection which is currently a requirement for all trains that run on LU infrastructure. (The latter is currently the subject of a risk based assessment between Chiltern Trains and London Underground). As for the remaining two options, there is no doubt that in terms of system safety, SPAD risk, over speed risk and legal compliance that Option 3 is the long term solution for deployment in the UK.

Although Option 3 is the overall long term solution for the UK, its early deployment is not feasible within the accelerated timescales. Despite Option 3 clearly bringing enhanced operational and safety benefits the current business case and deployment programme make this option non-viable due to its installation being based on the life expiration of the existing assets. Therefore not adhering to the current deployment plan will mean that its early implementation is neither cost effective nor feasible. The logistical challenges that face Option 3 also cast considerable doubt over its feasibility. These include but are not limited to resource constraints, migration issues and human factors assessments which are inherent more so in this option, and thus lead to further substantial complications. These difficulties are additionally compounded by accelerating the deployment of Option 3 and the impact that this would have on the national rollout strategy. Early deployment of Option 3 would also require a lengthy, expensive and demanding development process that resources and time may not allow.

Option 1 (Selcab ATP Life Extension) is the least viable option. 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. The SELCAB ATP currently installed on the Chiltern line was implemented in 1990; originally intended as a pilot for a UK wide ATP rollout. This, of course, never came to fruition, but what remains on Chiltern today is a 'pilot' protection system that is 25 years old and evidently life expired. It is of little surprise that maintenance engineers have been experiencing difficulty sourcing replacements of a technology that is a quarter of a century in age.

The report suggests that further investigation will be necessary in order to determine how the planned electrification of the Chiltern railway will affect the chosen option. Should the electrification have a significant enough impact such that it means that the Train Protection in place would have to undergo substantial modification, it would be judicious to coordinate the electrification with the rollout of the preferred option. This approach would avoid any unnecessary additional expense and complication of Train Protection modifications incurred by the electrification works.

In summary and given the constraints presented, it is the professional opinion of Mott MacDonald that Option 2 is the most viable option. Notwithstanding this, these conclusions are dependent on the timescales as we currently understand them remaining consistent. Should the rollout of ETCS be legitimately brought forward at a programme level from 2028 to around 2020 for example, then the life extension of the existing equipment may prove to be the most judicious and cost effective option.

1 Introduction

Mott MacDonald were commissioned by Network Rail to carry out a feasibility study into interim Train Protection solutions suitable for implementation on the Chiltern Railway mainline from 2018 to 2028, from when ETCS is due to be implemented. The present system will be life expired in 2018 and currently experiences and will continue to experience Reliability, Availability, Maintainability and Safety (RAMS) issues.

Three high level options were selected by the Chiltern ATP Steering Group (SG) for consideration by this report:

Option 1: Extension of life of the existing ATP system
Option 2: Deployment of enhanced TPWS provision (which includes option 2a, 2b and 2c for completeness)
Option 3: Accelerated migration to ETCS

In this report the three options above are explored in detail, with relevant permutations of the different options also presented and explored as 'sub-options'.

As of 2014, the primary train protection system that is used on the Chiltern network is an ATP system developed as one of two pilot schemes of ATP in the UK in the aftermath of the Clapham Junction Disaster in 1988. Installed in 1990, the system is known as "SELCAB" was originally developed by the Standard Electrik Lorenz Company in Germany. SELCAB bears similarities with the German Continuous train protection system LZB, as they are derived from common equipment platforms and use similar "loop" technology. As with LZB, applications of SELCAB were also made in Spain, however most of the Spanish installations have now been removed and replaced with LZB or ETCS, and such installations that remain whilst sharing the name, are technically quite different from the UK application.

The national ETCS rollout strategy is scheduling ETCS fitment to the Chiltern Railway network from 2028. The present obsolescence, reliability and availability issues with SELCAB have necessitated a need to explore whether or not the SELCAB ATP can feasibly and safely be maintained until this date, or whether a suitable interim system should instead be implemented, within present legislative constraints.

The safety critical requirements placed on train protection systems makes their correct application of paramount priority, as well as ensuring that Duty Holders in the Transport System are not subject to enforcement action.

2 Current System Baseline

2.1 Introduction

ATP in its simplest form provides automatic supervision of driver behaviour in relation to a train's adherence to signal aspects and speed restrictions and initiates a brake application. Should the equipment detect the driver is exceeding a safe speed related to signal aspects or maximum permitted speed. In the event of human error the risk of a dangerous situation developing is kept to a minimum. Following a spate of SPAD events in the 1980's, ATP was installed on Great Western Mainline (GWML) and Chiltern mainline as a pilot for the national rollout of ATP. Each train is equipped with a Vehicle On-Board Computer (VOBC), which relays information such as maximum safe speed at which the train may travel. The information the VOBC processes includes:

Rolling Stock
- Braking Characteristics
- Rollback detection
- Maximum permitted speed of vehicle

Infrastructure
- Gradient
- Line speed
- Distance to next loop location or target stop point
- Aspect displayed by lineside signals (in turn depending on the route set in the signalling system)

Information from the infrastructure is transmitted to each equipped train via long loops of cable in the four foot, which transfer information by magnetic induction to the vehicle's antenna. The VOBC only stores data relevant to the short section of track the train is traversing.

The loops of cable are interfaced to the signalling system or the infrastructure at various locations along the trackside, using Loop Electronic Units (LEUs). In each LEU, an Electric Programme Read Only Memory (EPROM) stores the relevant information for the next section of track (the permanent data) and the present signal aspect dependent data. The permanent and signal aspect dependent data stored in the LEU EPROM is then transmitted as a 70 bit telegram to the vehicle. The inductive loops also provide reference points for the distance measuring equipment on the train. The distance measuring equipment on the train depends on an odometer counting wheel revolutions, but which can easily get disturbed in conditions of low adhesion. Frequent lineside equipment updates are needed to keep the odometer data "up to date" to manage any risks arising from wheel slide conditions.

The VOBC processes the information from the LEU and sets a target speed (indicated by LEDs around the outside of the speedometer). In the absence of the driver action the ATP will apply the brake to bring the train down to the target speed, or if a train stop is required to the required stopping point (+/- 3%). The system stopping point is programmable according to the available overlap at each signal. If an overlap is available SELCAB can be set to bring the train to stop within a defined point within that overlap, if no overlap is available the LEU telegram data can be set to bring the train to a stop to the rear of the signal, i.e. the maximum allowable SPAD distance can be programmed into the LEU telegram data.

The train speedometer on ATP equipped trains provides indications to the train driver of signal aspects via Light Emitting Diode (LEDs) mounted in the speedometer facia, and an indication of permitted speed by LEDs positioned adjacent to each 5 mile/h speed increment around the periphery of the speedometer. The LEDs mounted in the speedometer facia also provide certain alarm indications to the driver depending on the trainborne ATP equipment health and status. Supplementary controls are also provided near the speedometer to enable the driver to release a brake application, and for use in shunting movements.

The ATP system provides a release speed to the driver. This reduces the effect of ATP supervising the train to stop at a signal which has cleared subsequent to the train passing the approach loop. When the Driver sees the proceed aspect he may pass the signal but must not exceed the release speed. The release speed is removed when the train receives new track data from the track loop.

Presently, 62 of the 68 vehicles in the current Chiltern rolling stock fleet are fitted with SELCAB ATP equipment, however this does not include freight that operates on the network, which is not ATP fitted. All Chiltern vehicles are fitted with Mk I TPWS, including ATP equipped vehicles, for operations off ATP equipped lines.

The extent of trackside fitment of ATP (covering all lineside signals and permanent speed restrictions) is

- Marylebone to Aynho Junction (exclusive) via Neasden South Junction and Princes Risborough,
- Princes Risborough to Aylesbury via Little Kimble
- Neasden South Junction to Harrow on the Hill (LUL Metropolitan Line) (exclusive)[1]
- Amersham London Underground (LUL) Metropolitan Line) (exclusive)[1] to Aylesbury Vale Parkway Station via Great Missenden.

N.B. the term exclusive means that location is a node not fitted with ATP equipment

2.2 Intermittent train protection systems

As the name suggests, intermittent train protection systems work on the basis that information is only passed ‘intermittently’ from track to train only at certain fixed locations.

As with all ATP systems (whether continuous or intermittent) the train driver remains responsible for the operation of the train, and particularly for observing signals and speed restrictions. The disadvantage of intermittent systems is that they can impact on capacity, particularly in conditions where “aspect improvement” is regularly encountered (e.g. approach control at junctions), as the driver may see a signal “improve” aspect, but the trainborne ATP will not react until the train receives an “update” from the next set of loops, which could be some distance ahead of the train.

[1] Some of the Chiltern rolling stock operate over LUL infrastructure between Harrow on the Hill and Amersham. Chiltern vehicles operating over that section of route are fitted with LUL Tripcocks (LUL’s primary form of Train Protection).

The train driver cannot accelerate as the system will behave on the basis of the more restrictive aspect that the train has previously received, and if he attempts to do so, an emergency brake application will be automatically triggered. To counter this, “infill” can be provided, e.g. additional loops and LEU’s are provided (over and above those that would be required to provide the minimum level of performance) to update the train at locations where “aspect improvement” could be expected.

Whilst continuous ATP systems (such as ETCS, TVM430 or LZB) can and do overcome the deficiencies of intermitted ATP systems, they are more expensive and costly than intermittent ATP systems.

The SELCAB ATP installed on the Chiltern Line is an example of an intermittent train protection system. An important factor in deciding on the way forward is to ensure that capacity on the network is not reduced, or if possible even enhance that capacity.

2.3 Operation of the Chiltern ATP system

The Chiltern ATP implements three types of supervision:

- Train trip (prior to passing a signal at danger)
- Continuous supervision of speed (NB: This is not the same as the ‘Continuous System’ described in 2.2)
- Rollback supervision and protection

2.4 Chiltern Rolling Stock with ATP fitment

Chiltern Railways have a total fleet size of 68 units, 62 of which are fitted with ATP. The distribution of this is shown below in Table 2.1.

Rolling stock type	Number of vehicles	ATP fitted?
Driving Van Trailer (DVT)	6	No
Class 165 Turbo sets	39	Yes
Class 168 Clubman sets	19	Yes
Class 172 Turbostar sets	4	Yes
Total:	**68**	

Table 2.1: Chiltern Rolling Stock

3 Option Summary

3.1 Introduction

From thorough investigation and discussion of the Chiltern ATP SG, three high level options were selected by the Chiltern ATP SG for consideration by this report:

Option 1: Extension of life of the existing ATP system
Option 2: Deployment of enhanced TPWS provision
Option 3: Accelerated migration to ETCS

The three options are to be assessed against the criteria as agreed by Network Rail:

- 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

These are addressed as chapters within this report.

3.2 Option 1: SELCAB ATP Life Extension

The first option proposed by the Chiltern ATP SG is the life extension of the current SELCAB ATP system.

3.2.1 System description

SELCAB ATP system offers continuous supervision of the following kinds:

- Train trip (when signal passed at danger (SPAD)
- Continuous supervision of speed (on track and shunting)
- Rollback supervision

The continuous supervision function supervises permissible speed and calculates braking curves. Driver violation of supervisions results in the VOBC implementing a reaction appropriate for the situation, whether that is a warning, service brake application or emergency brake application.

This supervision is transmitted from track to train electromagnetically by means of the inductive loops described earlier. These loops are laid in the four foot, varying in length from 5m - 300m, but most of which are 300m and generally placed on the approach to main line signals, or permanent speed restrictions.

The inductive loops are capable of informing the train of:

- The distance to next stopping point, whether it be a red signal or end of line,
- The distance to next loop
- The gradient of the line
- The length of overlap at next the next signal
- The loop ID number
- The loop length
- Speed restrictions
- Any start-up restrictions
- Signal aspect information
  - (SYSTEM DESIGN RULES (C713-SYST-UTILS-DES), 1991)

The VOBC decodes telegrams, calculates braking curves and speed supervision and interfaces the resulting information to the Driver Interface Unit (DIU) and to the vehicle.

3.2.2 Highlighted option attributes

For this option to be feasible it is necessary to ensure that the following requirements can be met:

- Any life extension work will not be in conflict with legal provisions arising from TSI's and the ROGS regulations which basically only permit the installation of Class A and Class B systems as defined in the CoCo Sig TSI 2012/88/EU. – The SELCAB ATP system is neither Class A nor Class B.
- Any re-engineered replacement parts can be implemented without impacting on the safety justification of the SELCAB ATP system

  - Current and future availability of spares of SELCAB components, including whether there is a risk of suppliers have discontinuing production of SELCAB components.
  - Adequate 1st and 2nd and 3rd line [for incidents and accident investigation] of maintenance support are available for the entire duration of the extension.
- The availability of an adequate knowledge base in both suppliers and operators (Railway Undertakings and Infrastructure Managers) for the SELCAB ATP. At least the design level of system safety can be maintained for the duration of the extension
- There is adequate provision of parts and components to facilitate infrastructure and train service enhancements over the life extension period, including the fitment of SELCAB ATP to additional vehicles.
- The whole life cost of the extension is competitive with the other options considered in this report.

3.3 Option 2: Deployment of AWS and Enhanced TPWS to Replace ATP

Option 2 is to take the ATP equipment out of use on both infrastructure and vehicles, and instead rely on TPWS and AWS installed on all main line signals and to upgrade all of the rolling stock's current Mk 1 TPWS units to TPWS Mk 3 or Mk 4 units. Currently, AWS is already fitted on every plain-line signal; however TPWS is only fitted on a proportion (~40%) of main line signals, in accordance with the regulations and Network Rail Company Standards.

3.3.1 System description

TPWS uses 'grids' to ensure train safety by ensuring that they can halt within the safe overrun distance (SOD), should they erroneously pass a signal which is at red. This is accomplished by an Over Speed Sensor (OSS), typically 400 to 200 metres before the signal, and a Train Stop Sensor (TSS) at the foot of the signal. These grids are only energised when the signal they protect is at red. Should the train be travelling too fast, the OSS triggers the emergency brakes, and should the train pass the red signal, the TSS triggers the emergency brakes. These measures should then brake the train to standstill before it reaches a point in which it is endangered or it poses danger.

In practice, each "grid" (whether part of an OSS or a TSS) is an aerial, and the grids are, in effect paired, the first loop encountered by a train being an "arming" grid, and the second being a "trigger" grid. When a train detects an energised "arming" grid, a timer is started on the train, and if the timer "expires" before the "trigger" grid is encountered, then the on-board system is reset, and no brake application takes place. If the timer is still running when the "trigger" grid is encountered, then an emergency brake application results. In an OSS arrangement, the arming and trigger loops are separated by a suitable distance relative to the duration of the timer which determines the speed which is not to be exceeded. The duration of the timer is a fixed value common to all passenger trains, and there is also a timer of fixed but different duration, fitted to freight locomotives.

In a TSS arrangement, the arming and trigger loops are abutting in a single assembly, resulting in there being a very short time between the arming and trigger grids, and therefore a brake application immediately being initiated if the loop is "energised" by a red signal.

As noted above, the main distinction between SELCAB ATP and TPWS are as follows:

- SELCAB ATP is fitted to every lineside signal and permanent speed restriction, and provides continuous speed supervision, whereas TPWS is fitted to signals protecting conflicts only, and has limited capabilities to protect over-speeding
- With SELCAB ATP, the braking calculation is carried out on-board, and is therefore relevant to the characteristics of the vehicle in question, whereas the design of trackside TPWS is a compromise based on a generalised assumption about train braking capability, which may not be effective for all trains cleared to use a route
- The design of TPWS at conflict locations has to be optimised to provide a level of protection based on a level of risk arising from potential signal overruns and the emergency braking capabilities of trains, whereas ATP protects conflicts automatically
- SELCAB ATP has a defined design level of safety integrity, considered to be SIL 2 as defined in IEC 60158, whereas TPWS has no defined level of safety integrity as defined in IEC 60158
- TPWS provides no protection in the event of a signalling power supply failure, whereas SELCAB ATP (like any ATP system) would provide warnings and possibly an emergency brake application in the event of a signalling power supply failure causing a loop not to be energised, or a signal to be "out".
- TPWS is assessed to be 70% effective at preventing ATP preventable accidents (Davies, 2000).
- SELCAB ATP is not listed as a Class B system as defined in the CoCo SIG TSI 2012/88/EU, which is mandated on the Main Line Railway under ROGS regulation 5, but TPWS is.
- SELCAB ATP meets the "reasonably practicable" definition of a train protection system providing control of SPADS and over-speeding, but TPWS only meets the default minimum provision against collisions, but not over-speeding, in the Railways (Safety) Regulations 2011.

The current infrastructure has TPWS TSS grids and OSS grids installed on around 40% of the signals fitted with ATP (~90/225). Depending on what the desired outcome would be in terms of the safety objectives related to any use of AWS and TPWS in lieu of ATP, Option 2 could therefore involve:

- Reviewing the current installations of TPWS to validate whether they are appropriate for wholly TPWS fitted rolling stock throughout the operating day, rather than the present approximately 25 TPWS trains per operating day.
- The installation of additional TPWS on at least 135 signals, and at other locations in the case of this option needing to demonstrate safety equivalence with the present ATP system Considering special TPWS trackside installation rules to create a situation where, under TPWS, signals are not passed at danger, and taking advantage of the relative homogeneity of Chiltern Rolling Stock emergency braking capability
- Considering whether algorithms can be developed to enable the protection of permanent speed restrictions with TPWS, taking advantage of the relative homogeneity of Chiltern Rolling Stock braking capabilities, whilst maintaining compatibility for other types of Rolling Stock.

- Carefully considering what types of Rolling Stock have access to the Chiltern Lines between Marylebone, Aylesbury and Aynho junction, in relation to any specific TPWS engineering rules
- Strengthening or improving the quality of signalling power supplies to minimise the risk of TPWS grids not being energised when required.
- Require Network Change and possibly Rolling Stock Change under the Network Codes, therefore subjecting the parties concerned to claims for any costs arising.

It is not clear either whether this option can be implemented within the capabilities of the present interlocking system, or whether this option will the need to upgrade the interlocking to a later version, such as Westlock or Smartlock.

The TPWS MK 3 and 4 Rolling Stock upgrades provide enhanced protection against reset and continue SPADS. Both MK 3 & 4 units also provide continuous 'health' monitoring. However Mk 4 provides a voice warning in the event of SPAD and visual indication of trip explanation e.g. OSS/AWS/TSS etc. It would seem apparent from the implicit requirements that a retrofit could be needed on all of Chiltern's current complement of Rolling Stock (71 vehicles, i.e. approximately 142 cabs) as part of any decision to dispense with the current ATP system.

It is understood this Option only provides for retrofitment of TPWS Mk 3 only to all Chiltern's passenger driving cabs, as a previous report commissioned by Chiltern Railways deemed the cost of Mk 4 to outweigh the monetised safety benefit (Sotera, 2014).

The trackside infrastructure aspect of Option 2 can be broken down into 3 sub-options:

Option 2a: Fitting only unfitted signals with TPWS

The degree of protection and reliability of the TPWS currently installed on 40% of the signals may be sufficient for the interim solution, therefore, normal TPWS fitment will only be required on the remaining 60% (~135) signals.

Option 2b: Refitting all signals with TPWS

It may be the case that the current TPWS trackside fitment is not sufficient to fulfil the safety/performance requirements and concerns have been expressed by maintenance engineers over the reliability and maintainability of the current TPWS. Therefore, subject to further investigation, it may be deemed necessary that an entire re-fitment of all signals with TPWS may be required.

Option 2c: Fitting all signals with TPWS with ATP functionality

It is possible to engineer TPWS so that the installation largely mimics the protection functionality of ATP.

Although the rollback and driver display will still be lacking, and the speed supervision will never be truly continuous, Tables 3.1 and 3.2 show a configuration of between 10 and 16 TPWS grids (depending on the braking characteristics assumed) that will give a level of protection close to that of ATP.

Where ATP uses braking curves to continuously supervise speed to, the strategic placement of TPWS grids, with speed restrictions that essentially follow what the braking curve would be, were it an ATP system. Figure 3.1 shows a curve of TPWS speed restrictions plotted against distance to signal, and the shape is similar to what would be expected of an ATP braking curve. It is worth noting that both ATP and TPWS aim to bring a train to a stand before the overlap of the signal so both provide the same level of overrun mitigation. Figure 3.1 serves only as an example of how Option 2c might be deployed, the final design of TPWS configuration would be subject to a thorough optioneering process and detailed design for each individual signal, should Option 2c be selected.

The suggestions in this section detailing Option 2c should be regarded as conceptualisation of Option 2c, and thus all findings are subject to further scrutiny.

Figure 3.1: TPWS Grid Placement against speed limit of the grids

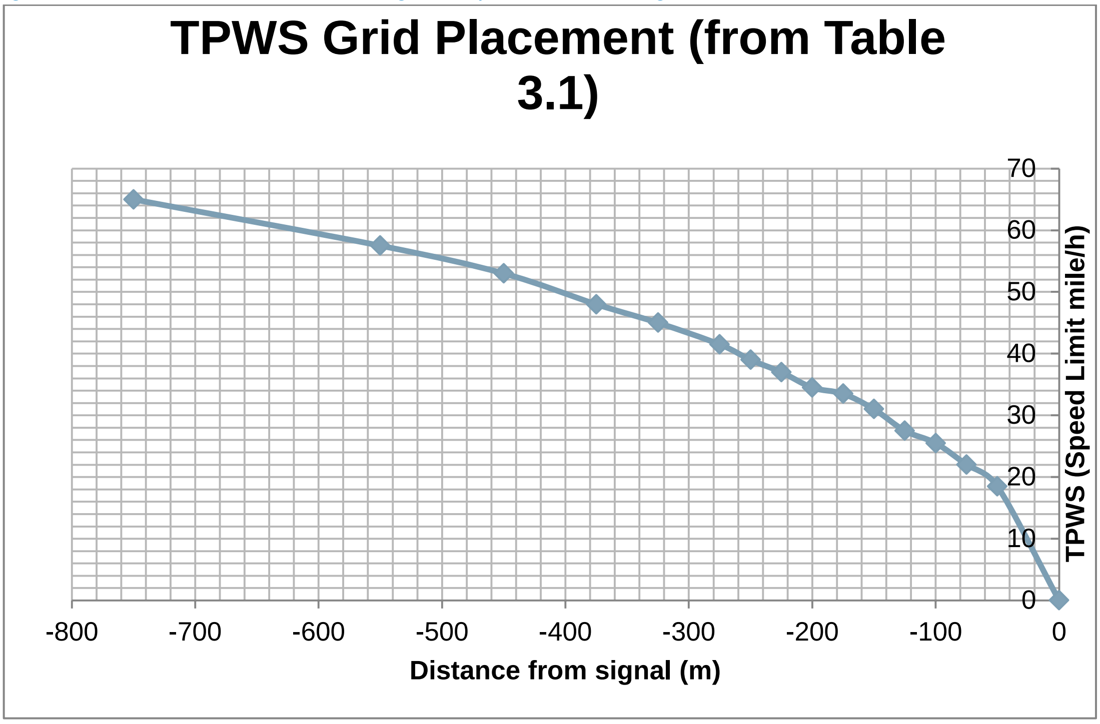


Table 3.1: Attempting to use TPWS to replicate the braking supervision functionality of ATP braking (9% g and mile/h braking being required)Train travelling in excess of 65 mile/h but braking at 6% g service brake curve rates Level Gradient on approach to a plain line signal

	OSS fitment distance m	OSS Set speed mile/h	Braking distance @ 9% m	Braking distance @ 12%g m	Worst case Scenario of a Train creeping under the set speed before being brought to a stand in relation to the signal @ 9%g mile/h	Worst case Scenario of a Train creeping under the set speed before being brought to a stand in relation to the signal @ 12% mile/h	Notes
	750	65	536	417	214.00	333.00	A train could sneak under the set speed by 0.1mph therefore the next set of loops will have to be placed at a distance which would enable a train to be brought to a stand before the signal. In the first set of figures, as a train could theoretically be travelling at 64.99MPH and not cause the OSS to activate the emergency braking, the maximum braking distance, at 9%, which could be required, is 536m. Thus by placing the next OSS loop in excess of the required distance a train will be brought to a stand before a SPAD will take place. A negative number indicates that the train will come to a rest beyond the signal. This is then repeated for each set of loops to determine the position of the next set of loops.
	550	57.5	426	332	14.00	133.00	
	450	53	365	286	24.00	118.00	
	375	48	304	239	10.00	89.00	
	325	45	269	212	21.00	86.00	
	275	41.5	232	183	6.00	63.00	
	250	39	207	164	18.00	67.00	
	225	37	188	149	18.00	61.00	
	200	34.5	166	132	12.00	51.00	
	175	33.5	157	125	9.00	43.00	
	150	31	137	109	-7.00	25.00	There is no standard OSS position between 175m and 157m (the braking distance in the line above) thus 150m will need to be used.
	125	27.5	110	89	-12.00	16.00	
	100	25.5	96	78	-10.00	11.00	
	75	22	74	61	-21.00	-3.00	
	50	18.5	55	46	-24.00	-11.00	
TSS	0	0	0	0	-55.00	-46.00	

Table 3.2: Attempting to use TPWS to replicate the braking supervision functionality of ATP braking (12% braking being required)Train travelling in excess of 65mile/h but braking at 6% service brake curve rates Level Gradient on approach to a plain line signal

	OSS fitment distance m	OSS Set speed MPH	Braking distance @ 9% mile/h	Braking distance @ 12% m	Worst case Scenario of a Train creeping under the set speed before being brought to a stand in relation to the signal @ 9% m	Worst case Scenario of a Train creeping under the set speed before being brought to a stand in relation to the signal @ 12% m	Notes
	750	65	536	417	214.00	333.00	A train could sneak under the set speed by 0.1mph therefore the next set of loops will have to be placed at a distance which would enable a train to be brought to a stand before the signal. In the first set of figures, as a train could theoretically be travelling at 64.99MPH and not cause the OSS to activate the emergency braking, the maximum braking distance, at 9%, which could be required, is 536m. Thus by placing the next OSS loop in excess of the required distance a train will be brought to a stand before a SPAD will take place. A negative number indicates that the train will come to a rest beyond the signal. This is then repeated for each set of loops to determine the position of the next set of loops
	450	53	365	286	-86.00	33.00	
	325	45	269	212	-40.00	39.00	
	225	37	188	149	-44.00	13.00	
	150	31	137	109	-38.00	1.00	
	125	27.5	110	89	-12.00	16.00	
	100	25.5	96	78	-10.00	11.00	
	75	22	74	61	-21.00	-3.00	There is no standard OSS position between 100m and 78m (the braking distance in the line above) thus 75m will need to be used
	50	18.5	55	46	-24.00	-11.00	
TSS	0	0	0	0	-55.00	-46.00	

3.3.2 Highlighted option attributes

- Although the replacement of ATP with TPWS results in a loss of functionality, the increase in safety risk on the ATP fitted rolling stock is counteracted by the decrease in risk on the non-ATP fitted rolling stock. Therefore there is a net reduction in risk (Sotera, 2013). The Sotera risk assessment report indicates that TPWS (or TPWS+ where line speed is greater than 75mph) fitted to every plain line signal and an on-board TPWS upgrade (MK3 or MK4) on all rolling stock would give rise to a 9% decrease in Fatality and Weighted Injury (FWI) risk across the whole Railway compared with the current ATP (Sotera, 2012).
- The current Mk 1 units installed on the current rolling stock are recommended for upgrade due to certain weaknesses of the Mk 1. Mk 1 units have a 'reset and continue' functionality that has meant that drivers have erroneously overridden TPWS intervention at SPAD.
- The on-board TPWS upgrades alluded to earlier reduce the accident risk (Fatality and Weighted Injury risk) by 34% for MK3 upgrade and 40% for a MK4 upgrade when compared with the current MK 1 equipment.

  Any proposals to deploy TPWS in standard configuration is likely to lead to an increase in SPADs over time compared with the current situation with ATP, as TPWS in standard configuration does not prevent them (unlike ATP which has SPAD prevention measures). This likelihood will therefore need careful consideration in the development of any proposals for TPWS in lieu of ATP.
- For approval to deploy TPWS in place of ATP each signal must be assessed using a Signal Overrun Risk Assessment Tool, or SORAT, and overall the level of risk associated with TPWS must be the same or less as ATP.

  For each signal the SORAT looks at the following:
  - The Infrastructure (distances between signals, line speed proximity to point work etc.)
  - The Timetable (the number, speed and frequency of trains at that signal)
  - The Rolling Stock (the type of train and its braking characteristics)
  - The signal itself (data taken from the signal sighting form)

    These variables are then processed and each signal is given a score, to allow for comparison and to enable alternative methods to lower the score of the signal to be determined

  Despite the best endeavors of the project team, an example SORAT assessment was not able to be achieved for this report.
- Option 2 provides a straightforward migration strategy as when ETCS is due for implementation on the Chiltern Network the trackside will either be fitted with TPWS or TPWS and ETCS, and the rolling stock will be fitted with either TPWS, ETCS or both, and therefore all rolling stock will have protection.
- The present ATP system is not a Class B system as defined in the Command, Control and Signalling TSI 2012/88/EU, which TSI is mandated on the infrastructure in question via ROGS Regulation 5. TPWS is such a Class B system, so it would be consistent with the requirements of the TSI and ROGS Regulation 5 to replace a non-class B system (SELCAB ATP) with a Class B system (TPWS).
- The requirements of the Railways Safety Regulations state that ATP (rather than TPWS) should be provided where "reasonably practicable", and thus any proposal to replace ATP with a different system, (unless it can be shown to deliver the same benefits or greater than ATP) is therefore known to require

special dispensation from the ORR against the Railways Safety Regulations 1999. The precise grounds for the dispensation have yet to be determined.

- Some trains on the Chiltern Network require access to LU infrastructure and it is an LU requirement that any rolling stock operating on their network is fitted with roll back protection (LUL, 2011). This requirement poses a challenge for Option 2, where there is no inherent roll back protection with TPWS. Chiltern railway are currently in discussions with LUL and have negotiated that a Risk Based approach will be taken to mitigate the dangers posed by the function not being available on Chiltern rolling stock. It is worthy of note that roll back protection is not an issue unique to Chiltern, and is in fact a concern on a national level with regard to risk reporting for all vehicles operating on the UK rail network,

3.4 Option 3: Accelerate Chiltern ETCS Deployment

Option 3 is the acceleration of the ETCS fitment to the Chiltern Railway Line, currently due to start in 2028.

3.4.1 System description

ETCS is the standard European Signalling system, which is mandated in Law under the provisions of the Command Control and Signalling – Technical Specification for Interoperability (TSI) 2012/88/EU and ROGS regulation 5. As part of ETCS, ATP is provided which is directly equivalent or even superior to that provided by SELCAB ATP, and therefore meets the requirements of the ROGS Regulations and the Railways (Safety) Regulations 1999. ETCS can be deployed in different forms, which are summarised below:

- ETCS Level 1 Limited Supervision: Application of ETCS to defined signals protecting conflicts and hazards only – similar to TPWS – but providing continuous speed and train protection. Lineside signals retained, and driver obeys lineside signals. Train needs fitting with full on-board subsystem. Existing cab display can be retained. Infill can be provided by loop or radio where needed.
- ETCS Level 1: Application of ETCS with intermittent data transmission (very similar in concept to SELCAB ATP) at every signal and speed restriction or other hazard, includes infill by loop or radio where needed. Train needs fitting with full on-board subsystem. Lineside signals retained, and driver obeys both cab display and signal aspects.
- ETCS Level 2: Application of ETCS with continuous data transmission. Train needs fitting with full on-board subsystem. Lineside signals can be retained or discarded. Driver obeys cab display.
- ETCS Level 3: Application of ETCS with continuous data transmission and train integrity monitoring. Train needs fitting with full on-board subsystem. Lineside signals discarded. Driver obeys cab display. (No practical implementations currently).

ETCS therefore offers a form of ATP that can be customised to the specification of the user.

Under the provisions of the TSI, each Member State is required to publish a migration plan to achieve ETCS fitment, and under the UK Member State Plan, the Chiltern mainline is planned to be fitted in 2028.

The Chiltern mainline is planned to be fitted with ETCS Level 2, i.e. with continuous transmission including the following functionality:

- Continuous speed supervision
- In-cab signalling
- Rollback supervision and protection
- System failure monitoring

The ETCS rollout strategy is being managed by Network Rail as a National Industry Programme and consists of two main parts:

- Trackside Infrastructure Fitment
- Rolling Stock Fitment

The Infrastructure programme is being managed and developed by Network Rail through their supplier framework agreements.

The rolling stock programme is being carried out by three separate projects:

- Passenger Rolling Stock
- Freight Rolling Stock
- Engineering Vehicles

The passenger rolling stock programme is being managed by the Rolling Stock leasing Companies (ROSCOs), who are producing first in class designs for each class of rolling stock. Fleet fitment is then being carried out by the Train Operating Companies (TOCs) as part of their refranchising process.

The freight rolling stock programme is being developed by Interfleet on behalf of Network Rail and the Freight Operating Companies (FOCs).

Fitment of the engineering vehicles is being managed by Network Rail.

3.4.2 Highlighted option attributes

- Due to its functionality ETCS Level 2 will offer a level of train protection that fulfils the legal requirements, and removes the conflicting legislative requirements of the TSI (through the ROGS regulations) and the Railways (Safety) Regulations.
- Migration from the current ATP system or existing Class B TPWS system to the new ETCS Level 2 system will be challenging in both cost and timescales, and will require careful consideration of a suitable migration strategy to address the needs of both the infrastructure, and vehicles and the compatibility between them.
- The costs of deploying ETCS in its final configuration would be substantial, both in terms of infrastructure engineering, and particularly in terms of Rolling Stock Engineering, and especially to maintain compatibility with other Rolling Stock with access rights to the Route.

- Class 172 Turbostar and Class 168 Clubman sets do not have the physical space in the cabs to accommodate both ATP and ETCS. This is a significant hurdle considering this represents 34% of the Chilterns rolling stock.
- Chiltern Railways will gain 5 additional class 170s from First Transpennine Express in May 2015, with another four being added to the fleet in May 2016 as part of a rolling stock cascade in the North of England
- The retro fitting of Rolling Stock alone, on the basis of the existing 68 units, is estimated at a budgetary price of around £20M-£30M, with other infrastructure costs in addition. It is likely that substantial signalling costs could arise, with the potential need (like Option 2) for interlocking replacement and substantial improvements to signalling power supplies, with a potential outturn in the order of £100M.
- Notwithstanding these costs, it is possible that this option would mitigate many of the risks arising with the other two.
- It is highly likely that the industry does not possess the sufficient technical resources to deliver this option for 2018.

4 System Safety

4.1 Option 1: SELCAB ATP Life Extension

The ATP system offers a comprehensive form of train protection due to continuous supervision. ATP offers protection against SPAD, over speed and rollback.

Speed restriction information, distance to next stopping point, gradient information, signal aspect and the length of the overlap at next signal is transmitted to the train by the trackside infrastructure (via induction loop). Using this information the VOBC provides background supervision by calculating braking curves and enforcing speed restrictions where necessary, by implementing service or emergency brakes.

All braking curves except the emergency brake are supervised to the foot of the signal. The emergency brake curve is supervised to any required point as set by the LEU telegram data, if the signal location has little overlap, and then the emergency brake curve can be set to stop the train at the signal (C713-SYS-FUN, 1991).

The speed supervision also includes provision for Temporary Speed Restrictions (TSRs) and Permanent Speed Restrictions (PSRs). Speed restrictions can be implemented by the programming of system EPROMs, which is somewhat of a cumbersome exercise. Speed supervision can also be customised for different types of rolling stock.

The system also offers a level of safeguarding against loop failure. ATP loops transmit the distance to next loop and in the event of loop failure the train VOBC implements the service brakes and informs the driver that they now have full responsibility for the safety of the train.

An additional feature of the Chiltern ATP is the inclusion of rollback protection.

Therefore SELCAB ATP offers a considerably more effective form of train protection than TPWS by comparison.

4.2 Option 2: Deployment of Enhanced TPWS to Replace ATP

TPWS as currently installed is assessed to be 70% effective at preventing ATP preventable accidents, which is of course is a significant reduction when compared to the protection that ATP is suggested to achieve (Davies, 2000).

However, as only 62 of the 68 vehicles in the Chiltern fleet are fitted with ATP, the Sotera risk assessment report indicates that TPWS fitted to every main line signal and an on-board TPWS upgrade (MK3 or MK4) on all rolling stock would give rise to a 9% decrease in FWI risk across the Chiltern network, as a whole, compared with the ATP and TPWS situation that currently exists (Sotera 2012).

It must also be noted that as 62 of the 68 Chiltern fleet are ATP fitted, and although Option 2 does not offer the same level of protection as the current ATP, TPWS fitment to every signal could still offer an improved level of protection for the 5 units of Chiltern rolling stock not fitted with ATP, plus those Railway Undertakings other than Chiltern having access rights to the Chiltern Lines.

As there are other operators running over the ATP fitted route, the increased provision of TPWS reduces the risk of the other operators being involved in an incident, i.e. the overall risk of operation (Chiltern + Other Operators) is reduced.

The Key issues arising with this option are:

- Determination of the objectives of ATP replacement – (e.g.) maintaining the level of SPADS as now, maintaining the level of collision risk as now, or controlling the over speed risks, as now, or some combination of these, or others;
- Determining the “reasonably practicable” basis on which substitute functionality for ATP would be provided, and the acceptability of this to the Safety authority; under the Railways (Safety) Regulations 1999
- Making proper provision for the not inconsiderable capital costs that could arise from the engineering that could be necessary to the infrastructure to achieve anything approaching substitute ATP functionality;
- Making proper provision in the life cycle costs for the increased level of SPADS likely to arise, including the distraction of management effort to investigate them;
- Managing the “political” appearance of any such proposal, given the likelihood that the immediate trend following the turning off of ATP is likely to be an increase in SPADS, which are considered accident precursors, and therefore could challenge the acceptability of that increase to industry stakeholders.

Based on the Sotera report, the on-board TPWS upgrades alluded to earlier reduce the accident risk by 34% for MK3 upgrade and 40% for a MK4 upgrade when compared with the current MK 1 equipment.

The main challenges are that TPWS:

- Cannot provide continuous speed supervision
- Does not offer rollback protection
- Is less effective at reducing SPADs when compared with ATP.
- Furthermore, where TPWS is generally designed to supervise trains with a 12%g or at best 9%g braking capability, there is still a proportion of the trains operating on the network that will be at risk since they cannot provide this level of braking capability. However, all passenger trains work at 9%g, and a relatively small proportion of freight trains cannot deliver the recommended braking performance. Additionally, no freight trains are fitted with ATP, and therefore an extended TPWS fitment on the Chiltern line will actually reduce risk overall (Sotera, 2012).

4.3 Option 3: Accelerate Chiltern ETCS Deployment

ETCS by definition includes ATP, and offers similar or better functionality to that of the current ATP, depending on which level of ETCS is chosen. ETCS Level 1 Limited Supervision and ETCS Level 1 both provide equivalent train protection to the existing ATP system, including TSRs and PSRs based on intermittent transmission from trackside to train, but at the expense of fitting the existing rolling stock with a full on-board subsystem. ETCS Level 2 offers an enhanced level of train protection using continuous data transmission between infrastructure and train via Global Systems Mobile Communications- Railway (GSM-R), can enforce TSRs and PSRs and can give protection against rollback, and with the potential to improve network capacity by permitting reduced headways between trains.

As all information is constantly updated via GSM-R, ETCS Level 2 has the potential to deliver real-time information to the train, enhancing the level of protection and reducing the need for unnecessary braking. All levels of ETCS have the ability to detect balise failure by trainborne monitoring of balise uplink sequences. In the event of balise discontinuity the system can give the driver an in-cab alert or apply the emergency brake.

The main challenge with ETCS is the lack of experience in its widespread application to “brownfield” railways, and the challenges that can arise when engineering the application to the site circumstances, and particularly where, as in the UK, the Infrastructure Manager and Railway Undertaking(s) concerned are commercially segregated organisations.

4.4 Option comparison

Table 4.1: System Safety Option Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
Continuous speed supervision	No continuous speed supervision	Continuous speed supervision
Rollback supervision	No rollback protection	Rollback supervision
Loop failure detection		Balise failure detection
Enforce TSRs and PSRs	Can enforce PSR's only (PSR's too expensive/complicated)	Enforce TSRs and PSRs
Protection determined by Rolling Stock	One size fits all type deployment rules, giving better protection for some trains than others	Protection determined by Rolling Stock
	9% improvement in risk compared with ATP over whole Railway	
	Increased collision risk for trains with less than 9% emergency brake.	
Decreasing knowledge base	Well understood system	Poor understanding of new system

Key
Advantage
Disadvantage

5 Integration Requirements/Risk

5.1 General: Electrification Issues

For any of the options consideration must be given to the plans to electrify the Chiltern mainline in mid-2020's, in line with emerging electrification strategies. Electrification can cause problems particularly to trackside infrastructure, so any solution chosen must be compatible. If the line is electrified then the system must be immune to the traction return currents, track to earth fault voltages, and induction between traction cables and trackside signalling cables and thus electrification could potentially force replacement of some of the signalling equipment before the 2028 ETCS fitment date.

Electrification also has a profound impact on the use of track circuits. It is entirely possible that the track circuits would need to be completely re-engineered, and this would likely result in the re-engineering of any Train Protection system installed. If this is the case, it would be judicious to coordinate the implementation of the chosen Option for the Chiltern ATP extension/replacement with the electrification plans, in the order to avoid incurring the cost of re-engineering/re-installation.

5.2 Option 1: SELCAB ATP Life Extension

The principle risk at present is that the obsolescence and loss of knowledge in the system is leading to a level of unreliability which has the potential to accelerate to the point where safety can be called into question.

There is not an obvious "do nothing" option available that will prevent the current system becoming sufficiently unreliable as to be of doubtful fitness for purpose, which is, in itself, a considerable safety hazard, and could expose both Network Rail and Chiltern Railways to enforcement action if nothing is done.

It is not known whether the SELCAB system has been approved for use in a 25kV 50Hz Electrification environment. Given that the parent application is in Germany, where there is a 15kV 16 2/3 Hz electrification environment, unless the manufacturer knows positively to the contrary, it is likely that assessments will need to be carried out on the SELCAB system for immunity to 25kV 50Hz electrification as part of any Electrification.

It is also likely that by the time electrification comes to the Chiltern lines, the SELCAB system will have been replaced, or indeed needs to be replaced as part of electrification by an ETCS based system.

In any case, the introduction of electric traction power will require modifications to whichever signalling system is present (such as fitting Automatic Power Control (APC) magnets to trackside and receivers on trains). Therefore the replacement of SELCAB with an ETCS based solution should be able to incorporate the electrical signalling requirements to the train-borne equipment at the time of installation to accommodate the requirements.

5.3 Option 2: Deployment of Enhanced TPWS to Replace ATP

Not only would signalling design, installation, testing and commissioning be needed for the TPWS on currently unfitted signals (approximately 135 signals), it is likely that reassessment and redesign would be required for some of the currently existing TPWS installations. This is because of changes in standards that govern the implementation of TPWS since it was initially rolled out. There is even the possibility, should upon detailed review the current system be found to not be in line with standards, a wholesale review of the application of TPWS to the Chiltern scheme would be needed in accordance with NR/L2/SIG/14201, due to the increase in proportion of trains depending on TPWS rather than ATP.

The anticipated levels of additional TPWS installations is also likely to drive the need for additional lineside SSI modules to accommodate the condition monitoring controls, which in turn may drive additional interlocking's, depending on the current allocation of interlocking capacity. In extremis, it is possible that at least an interlocking replacement could be required for this option.

The other area of challenge could be signalling power supplies, both in terms of spare capacity, and availability (given that TPWS requires a power supply to be effective). Re-engineering of power supplies could be a significant ingredient of any argument that TPWS could be any form of substitute for the existing ATP.

Additionally the rolling stock cabs would need to be fitted with the MK3/MK4 upgrade. The MK3 upgrade is simple to carry out, involving the simple swap of the existing cab unit for the new one. Installation of TPWS3 is by exchange of the TPWS1 Control unit with the TPWS3 unit. The TPWS3 unit is fully backwards compatible, so there are no other vehicle installation implications for change to TPWS3.

The speedometer panel will need to be changed from the existing ATP unit to a standard 6" speedometer of the type fitted to non-ATP vehicles. There are non-ATP versions of all three of Chiltern's ATP fitted vehicles – i.e. Chiltern Class 165 unit can use the same speedometer design as non-ATP Class 165 units operating out of London Paddington, the Class 168 units can use the Class 170 design and the Chiltern Class 172 units can use the same arrangement as the London Midland Class 172 units.

Figure 5.1: Chiltern Class 168 Desk

Figure 5.2: First ScotRail Class 170-4 Desk

However the MK4 upgrade is considerably more difficult to implement due to the larger size of the unit and the remodelling of the cab desk panels to accommodate the additional MK4 control panel functionality, annunciator unit and associated wiring.

TPWS is deployed in 25kV 50Hz electrification environments around the UK national rail network, and therefore this option should not create any significant immunisation problems, with the normally anticipated earthing and bonding arrangements.

TPWS is not used for neutral section management, as would be the case for an ETCS based solution, so if an ETCS based solution has not been implemented at the time of electrification, the means of managing electrification neutral sections will need to be considered.

5.4 Option 3: Accelerate Chiltern ETCS Deployment

Under the current UK ETCS rollout strategy, Chiltern Railways is not due to be fitted with ETCS until 2028. Therefore this strategy would have to undergo significant adaptation to facilitate the early fitment of ETCS to Chiltern. This of course will also have an impact on the rollout of ETCS on other lines. With the work that is involved with this, e.g. budget rework, planning alterations, administrative tasks; this is likely to be complicated and incur a not insignificant cost.

Non-ETCS fitted trains would still be able to operate over the Chiltern network, as they would retain the existing fitted TPWS system, until retro fitted with ETCS.

25kV 50Hz is a “target system” under the Energy TSI, and therefore any ETCS based solution will be compatible with this electrification system. ETCS also provides neutral section management facilities, which would avoid vehicles being fitted with other systems to manage them.

5.5 Option comparison

Table 5.1: Integration Requirements/Risk Options Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
System already Integrated	Design, install and commissioning needed for new TPWS equipment, and possibly new modules and power supplies, and possibly new interlocking	Design, install and commissioning needed for new equipment on trains and infrastructure
	Need for reassessment of lineside signals under NR/L2/SIG/14201, and new/additional modified TPWS installations to be provided	
		Alteration of national ETCS roll out strategy
		Migration strategy needed
		Compatibility with trains not fitted with ETCS

Key
Advantage
Disadvantage

6 SPAD risk

6.1 Option 1: SELCAB ATP Life Extension

Due to speed, distance and braking supervision, as well as train trip functionality, the risk of SPADs is perceived to be very low with the implementation of SELCAB ATP, although they do occur. As discussed in section 4.1, ATP supervises the train to the foot of the signal at red, braking automatically to ensure the signal is not passed. Therefore an ATP SPAD is very rare. The 2012 Network Rail Chiltern ATP risk assessment workshop categorised the SPAD risk of SELCAB ATP as ‘Highly Unlikely (Every 200 years)’, which roughly equates to a Fatality and Weighted Injury (FWI) of 1 fatality every 500 years (Network Rail, 2012).

However, due to release speed functionality of the Chiltern ATP, SPADs are not fully preventable with the SELCAB ATP.

As with any train movement, poor adhesion is likely to have an effect on the effectiveness on ATP, however there is a level of odometery correction in the event of wheel spin, so therefore some adverse effects are mitigated.

6.2 Option 2: Deployment of Enhanced TPWS to Replace ATP

TPWS does not directly prevent SPAD, but rather mitigates the consequences of a SPAD. TPWS can prevent over speed at set locations, however this is not commonplace, and more often, TPWS trips a train when it passes a signal at danger. It therefore has limited power to prevent a train from passing a signal at red as it depends on the train being able to come to a halt, when tripped, within the Safe Overrun Distance (SOD). However, as discussed in section 4.2, it is plausible that not all trains will not have the sufficient braking capability and as a consequence overruns the SOD in the event of a SPAD. As with any train movement, poor adhesion will also have a significant impact on the effectiveness of TPWS.

The 2012 Network Rail Chiltern ATP risk assessment workshop categorised the SPAD risk of TPWS as a ‘Remote Possibility (<4% Annual Probability)’, which roughly equates to a Fatality and Weighted Injury (FWI) of 1 fatality every 100 years (Network Rail, 2012).

The MK 3 and 4 Rolling Stock upgrades provide enhanced protection against reset and continue SPADS as far as vehicles are concerned. MK 4 units also provide continuous ‘health’ monitoring and a voice warning in the event of SPAD.

The main consequence of this option is therefore the potential for an increase in SPADs due to the requirements placed on TPWS by statute. This would potentially be contrary to the industry and regulatory objectives, which is to reduce them. This argument will need very careful management in the event of making any justification to the Safety Authority for a dispensation under the Railways (Safety) Regulations 1999 to regress from ATP to TPWS. This issue would have to be explored further in the detailed design stage, should this option be carried forward.

6.3 Option 3: Accelerate Chiltern ETCS Deployment

The continuous speed supervision & Movement Authority (MA) information means that ETCS offers increased protection against SPAD when compared with TPWS. Like the ATP system, ETCS supervises the train to the foot of the signal, and therefore the risk of SPAD is greatly reduced if not eliminated (assuming sufficient adhesion conditions, proficient train braking capabilities etc.).

The 2012 Network Rail Chiltern ATP risk assessment workshop categorised the SPAD risk of ETCS as 'Highly Unlikely (Every 200 years)', which roughly equates to a Fatality and Weighted Injury (FWI) of 1 fatality every 500 years (Network Rail, 2012).

6.4 Option comparison

Table 6.1: SPAD Risk Option Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
SPAD accident highly unlikely (Every 200 years/1 fatality every 500 years)	SPAD accident a Remote Possibility (<4% Annual Probability/1 fatality every 100 years)	SPAD accident highly unlikely (Every 200 years/1 fatality every 500 years)
	Poor adhesion has greater effect on TPWS	
	Likely increase in SPADs but can be mitigated by driver training.	

Key
Advantage
Disadvantage

7 Over-speeding risk

7.1 Background

As much of the ATP fitted infrastructure has a maximum speed of 100 mph, and the maximum achievable speed of the Chiltern Rolling stock is 100 mph, the risk of over-speeding is relatively low. Risk still remains in areas of PSRs and TSRs and on approach to restrictive signals, however there is minimal use of PSRs and TSRs on the Chiltern line so therefore any technology change is unlikely to have significant detrimental impact on risk, due to the factor of PSRs and TSRs alone.

7.2 Option 1: SELCAB ATP Life Extension

The risk of accidents caused by over-speeding is mitigated by the continuous speed supervision functionality of the Chilterns ATP system. ATP also provides differential speed supervision to different classes of rolling stock, as the braking performance of the ATP is set for the actual braking performance and speed capabilities of the rolling stock.

The 2012 Network Rail Chiltern ATP risk assessment workshop categorised the risk of as ‘Highly Unlikely (Every 200 years)’, which roughly equates to a Fatality and Weighted Injury (FWI) of 1 fatality every 500 years (Network Rail, 2012).

The Chilterns route is quite curved, and there is a high preponderance of differential speed restrictions arising from the incremental “Evergreen” enhancements that have taken place over recent years, some of which approach the limits permitted by track cant at some locations. The evaluation of the extent to which the ATP system is depended on for control of over-speeding risks at these locations will need to be evaluated in any proposal to abandon use of the SELCAB ATP system.

7.3 Option 2: Deployment of Enhanced TPWS to Replace ATP

The over speed prevention that is provided by TPWS is limited by the fact that, if provided, it is only implemented at specific points along the track and that it does not offer continuous supervision, so therefore, once the train has passed the speed trap it is free to maintain a high speed or even accelerate, which can mean that a train, if tripped at a train stop sensor, may overrun the safe overrun distance.

The statutory requirement for TPWS in the Railways (Safety) Regulations is as follows:

‘Where there is a speed restriction if– (i) the permitted speed on that approach is 60 miles per hour or more; and (ii) in order to comply with the restriction, a train travelling at the permitted speed on that approach would need to have its speed reduced by one third or more. This corresponds to the location where an Advanced Warning of Speed Restriction indicator would be provided at the lineside. The regulations recognise the limitations of TPWS for over speed management, and limit them to this single situation.’ - (The Railway Regulations 1999, 1999)

The 2012 Network Rail Chiltern ATP risk assessment workshop categorised the accidents from over speed risk of TPWS as a ‘Remote Possibility (<4% Annual Probability)’, which roughly equates to a Fatality and Weighted Injury (FWI) of 1 fatality every 100 years (Network Rail, 2012).

TPWS is designed to offer differential protection so that a higher speed restriction is enforced on Passenger rolling stock and a lower restriction enforced on Freight rolling stock. Where freight generally deliver an inferior braking performance when compared with the passenger rolling stock, differential protection can ensure that freight vehicles have adequate protection whilst not inhibiting the performance of passenger rolling stock.

It is not clear yet what TPWS arrangements could be introduced to control the over-speeding risks presently achieved through use of the ATP system, and whether those arrangements could be justified as meeting the requirements for an explicit risk estimation under the Common Safety Method (CSM), and particularly the requirement that the risk of a catastrophic failure being reduced to 10^{-9} per operating hour. However, it is unlikely that the task of route speed profiling the Chiltern line, with the objective of effective TPWS implementation, would pose a high level of program risk, as it is not deemed to be a complex or arduous task. The limited use of PSRs and TSRs on the line, coupled with the fact that the maximum speed of the Chiltern line cannot be feasibly exceeded by the rolling stock, means that the issue of over speed is unlikely to pose a significant risk increase.

7.4 Option 3: Accelerate Chiltern ETCS Deployment

Similar to SPAD risk, the risk of accidents caused by over-speeding is mitigated by the continuous speed and MA supervision functionality of ETCS. ETCS has the additional advantage, similar to ATP, of being able to offer differential speed supervision to different classes of rolling stock. Again The 2012 Network Rail Chiltern ATP risk assessment workshop categorised the risk of as ‘Highly Unlikely (Every 200 years)’, which roughly equates to a Fatality and Weighted Injury (FWI) of 1 fatality every 500 years (Network Rail, 2012).

7.5 Option comparison

Table 7.1: Over-speeding Option Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
SPAD accident highly unlikely (Every 200 years/1 fatality every 500 years)	SPAD accident a Remote Possibility (<4% Annual Probability/1 fatality every 100 years)	SPAD accident highly unlikely (Every 200 years/1 fatality every 500 years)
	Increased risk associated with trains travelling >75mph	
	Differential protection	

Key
Advantage

Mott MacDonald

8 Whole-life cost

Disadvantage

8.1 Assumptions

The whole life costs were estimated for both the capital costs (capex) and operating costs (opex). These have been estimated based on the following assumptions:

- Project start year: 2016
- Project end year: 2028
- Discount rate: 3.5% (based on UK Treasury *Green Book*)
- All costs are at 2014 prices

For each of the cost lines the Net Present Value of the cost over the appraisal period has been estimated, and this has been taken to be the whole life cost.

8.2 Option 1: SELCAB ATP Life Extension

Cost estimates for the extension of the SELCAB ATP life extension were obtained from the current supplier Thales. The unit rates for the cost lines are given in Table 8.1.

Table 8.1: Option 1: Cost Unit Rates

Item	Cost (£)	Source
Cost per VOBC and LRU	94,400	Thales
Cost per LEU set	13,500	Thales
Spares and maintenance per annum	125,000	Thales
Staff training (course development)	10,000	Thales
Staff training per annum	2,000	Thales
Tooling	135,000	Thales

Based on the informational available to the author at the time of compiling this report it has been assumed that the life extension will apply to 68 rolling stock units and 225 line side signals. The Capex prices consist mostly of purchase of spare components: Loop Reading Units (LRUs) and VOBCs for On train equipment and LEUs and LRUs for the trackside. Given these parameters, the whole life costs for Option 1 are given in table 8.2 below:

Table 8.2: Option 1: Whole Life Costs

Item	Cost (£)
Capex	
On train equipment	6,111,000
Trackside equipment	294,000
Total Capex	**6,405,000**
Opex	
Spares and maintenance	1,285,000
Staff training (course development)	10,000
Staff training per annum	21,000

Item	Cost (£)
Tooling	135,000
Total Opex	**1,450,000**

Thales also indicated that this would not be the preferred solution as it still carries a high risk of equipment obsolescence, due to the Germany-based factory's discontinuance of SELCAB parts production, although it is possible that LZB or SELtrack components could be used instead, subject to a degree of reengineering.

The alternative suppliers (Park Signalling) were unwilling to give an estimate as to how much they would charge to support the system.

8.3 Option 2: Deployment of Enhanced TPWS to Replace ATP

Both Capital and Operating Cost estimates for the deployment of enhanced TPWS to replace the current ATP were obtained from Mott MacDonald's own estimates as well as the Sotera Risk Solutions report, *Update to the TPWS model and assessing fleet changes,* June 2014. The cost estimates were based on two possible scenarios for undertaking the works. These were:

- Midweek working
- Possession working

The unit rates for the capex lines are given in Table 8.3 and for opex lines are give in Table 8.4.

Table 8.3: Option 2: Capex Unit Rates

Item	Cost (£)		Source
	Midweek Working	Possession Working	
Cost per Train Stop Sensor (TSS)	11,580	14,980	Mott MacDonald
Cost per Over Speed Sensor (OSS)	13,960	18,050	Mott MacDonald
Cost per 1/2 Location Case (LOC)	30,690	39,690	Mott MacDonald
TPWS upgrade Mark III cab unit	3,000	3,000	Sotera report
TPWS upgrade Mark IV cab unit	10,000	10,000	Sotera report

Table 8.4: Option 2: Opex Unit Rates per annum

Item	Cost per Annum (£)		Source
	Midweek Working	Possession Working	
Cost per Train Stop Sensor (TSS)	1,620	2,090	Mott MacDonald
Cost per Over Speed Sensor (OSS)	2,160	2,790	Mott MacDonald
Cost per 1/2 Location Case (LOC)	2,260	2,920	Mott MacDonald

It has been assumed that out of the 225 line side signals, 90 are currently fitted with TPWS equipment and 135 are not. Further, 62 Mark III carriages and 6 Driving Van Trailers (DVT) require an upgrade. Based on these assumptions, the whole life capex and opex for various Option 2 sub-options are given in Table 8.5.

Table 8.5: Option 2: Whole Life Costs (10 years)

Item	Whole Life Costc (£)	
	Midweek Working	Possession Working
Capex		
Fitment of TPWS equipment on train (Mark III equipment)	359,000	359,000
Fitment of TPWS equipment on train (DVTs)	17,000	17,000
Option 2a: Fitment of TPWS equipment on signals	11,338,000	14,664,000
Option 2b: Fitment of TPWS equipment on signals	18,896,000	24,440,000
Option 2c: Fitment of TPWS equipment on signals	154,784,000	200,198,000
Total Capex (Option 2a)	**11,714,000**	**15,041,000**
Total Capex (Option 2b)	**19,273,000**	**24,817,000**
Total Capex (Option 2c)	**155,161,000**	**200,575,000**
Opex		
Total Opex (Option 2a)	**19,215,000**	**24,852,000**
Total Opex (Option 2b)	**19,215,000**	**24,852,000**
Total Opex (Option 2c)	**162,523,000**	**210,208,000**

Details of the estimated cost per signal to fit TPWS in a traditional TPWS arrangement can be found in Appendix B.

However, it is unlikely that the costs stated above will be adequate, and need to include:

- The costs to re-engineer power supplies for the increased power demand
- The costs of creating the interlocking capacity to include condition monitoring of the increased quantity of TPWS
- The costs of investigating the increased amount of SPADS
- The increase in maintenance costs of the additional TPWS
- The costs associated with the increase in SPAD in terms of management time

Mark III rolling stock upgrade will be subject to the approval bodies accepting replacing TPWS1 with TPWS3 as acceptable under GE/RT8075.

As TPWS equipment has a life expectancy of at least 25 years, installation of new equipment may be considered a waste of financial resource considering only half of the life of the new equipment will have been utilised by the time ERTMS is installed (13 years/25 years).

Thales TPWS1 was introduced in 2001, which Thales superseded with TPWS3 in 2010 to “maintain continuity of supply and overcome obsolescence” (ref. Thales datasheet: 12710-TPWSSDatasheet-v6), thus TPWS1 has become obsolete in 9 years. The accelerating pace of electronics development suggests that a similar fate may befall TPWS 3 and TPWS 4, in short TPWS 3 and 4 will probably be obsolete before the proposed 2028 ETCS date.

8.4 Option 3: Accelerate Chiltern ETCS Deployment

Generating an accurate estimate for the whole life cost of ETCS systems is particularly difficult for a number of different reasons. For one, since ETCS is a relatively new technology, there aren't the numbers enough of previous applications to draw cost information from. Additionally each application tends to be unique, and costs might depend on baseline, level, and complexity of situation (straight line, complex node etc.). Furthermore, detailed cost information for this technology tends to be kept confidential.

However the UIC report, *ERTMS Implementations Benchmark,* September 2009 provides some information to base estimates on. This report has been used to estimates costs for Option 3. The unit rates for the cost lines are given in Table 8.6.

Table 8.6: Option 3: Cost Unit Rates

Item	Cost (£)	Source
ETCS Level 2 trackside subsystems (R&D costs per double track kilometre)	103,700	UIC report
ETCS Level 2 trackside subsystems (Investment costs per double track kilometre)	604,000	UIC report
ETCS Level 2 trackside subsystems (O&M costs per annum per double track kilometre)	7,800	UIC report
ETCS Onboard train fitment (per Cab)	270,000	UIC report

Based on a total of 184 km of double track, and the fitment of the 45 rolling stock that can be fitted with the ETCS on-board system, the whole life costs for Option 3 are given in Table 8.7.

Table 8.7: Option 3: Whole Life Costs

Item	Cost (£)
Capex	
ETCS Level 2 trackside subsystems (R&D costs)	18,444,000
ETCS Level 2 trackside subsystems (Investment costs)	107,452,000
ETCS Onboard train fitment[2]	24,300,000
Total Capex	**150,196,000**
Opex	
ETCS Level 2 trackside subsystems (O&M costs)	14,693,000
ETCS Onboard units	6,480,000
Total Opex	**21,173,000**

Changes to the network are to be carried out at Network Rail's cost and therefore are not included in these cost estimates.

8.5 Option comparison

Table 8.8: Delivery Option Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
Capex: £6,405,000	2a Capex: £15,041,000 (Poseession working)	Capex: £150,196,000
Opex: £1,450,000	2a Opex: £24,852,000 (Poseession working)	Opex: £21,173,000
	2b Capex: £24,817,000 (Poseession working)	
	2b Opex: £24,852,000 (Poseession working)	
	2c Capex: £200,575,000 (Poseession working)	
	2c Opex: £210,208,000 (Poseession working)	

Key
Cost < £20M
£20M < Cost < £100M
Cost > £100

2 This figure does not include the cost of the First in Class (FIC) fitment, which will be considerably more. The exact figure has not been made available so therefore was not included in estimations.

9 Delivery

9.1 Option 1: SELCAB ATP Life Extension

As mentioned in 3.2.2, supplier discontinuation of some SELCAB components means that difficulty is likely to be encountered in maintaining the system. Discontinued components will either need to be sourced from elsewhere or bulk purchased from the current suppliers, or adapted from related systems such as LZB and Seltrac. Any such work will clearly not be a trivial exercise, however, if feasible (as suggested by the Atkins Report), could deliver the safest and lowest whole life cost option of the three, as present levels of safety and performance can be maintained, and there is potentially low risk of regulatory objection to the approach taken.

Clearly, any such approach needs to address the declining SELCAB knowledge base within the current system supplier (Thales) and within Network Rail. This is primarily due to staff retirement and staff turnover. Any such approach would need to consider the costs arising from training and maintaining necessary personnel knowledge of the system.

The initial stages of project delivery of Option 1 would involve engaging the current supplier and any potential alternative suppliers to accumulate a perspective of possible approaches to the life extention/obsolescence management of the ATP system. As the current SELCAB ATP is deemed to be obsolete, it can be expected that, in accordance with the 'Bath Tub curve' of product failure behaviour, the SELCAB ATP would experience increasing failure rates over the duration of the life extension. This assumption would appear to be supported by Section 13 which shows a significant increase in failures of ATP (and TPWS) from 2013 to 2014. Therefore the initial stages of delivering Option 1 would involve strategizing a clear plan of dealing with asset failure over the 10 year life extension. Ultimately the success of Option 1 lies in the chosen supplier's ability to deliver adequate maintanence to sustain the system for the entirety of the life extension.

However, from the lack of willingness to contribute to this study, and from the experiences of the client, it is clear that there is not a great deal of appetite to maintain the system from the current supplier. There are serious questions over whether the alternative supplier, Park Signalling, due to staff resourcing risks, will be able to deliver maintenance over the whole period of life extension.

9.2 Option 2: Deployment of Enhanced TPWS to Replace ATP

Option 2 has the advantages that it is a known system and therefore it is known how to deliver it. Equipment is also widely available, and it could also provide an easier environment for the movement of different rolling stock to the Chiltern lines, as there would be no requirement for ATP fitment.

The initial stages of the delivery of this project would involve the consultation of and collaboration with the regulatory bodies to ensure that a design within the scope of Option 2 can achieve approval from the authorities (ORR). Part of these initial stages might involve the drafting of a reference design to present to the regulatory bodies.

The main challenges with this option are:

- The higher residual risk of an ATP preventable collision arising, compared with the present ATP system, for the period until it is replaced with ETCS;
- The costs likely to arise from infrastructure enabling works to sustain the levels of TPWS likely to be needed, which will certainly at least require the upgrading of signalling power supplies, and possibly the need to create additional interlocking capacity, or even replace the interlocking's with a more modern equivalent;
- The likelihood of an increase in the number of SPADs arising once the ATP system is turned off (as SPADS are not prevented by TPWS, but are to a greater or lesser extent by ATP) with the consequences of the negative impression this can create with both regulators and public; as well as providing additional demands on incident investigation for supervisors and managers;
- The lower levels of intrinsic safety integrity of TPWS (SIL 0 as defined in IEC 60158) when compared with ATP (SIL2 as defined in IEC60158).

9.3 Option 3: Accelerate Chiltern ETCS Deployment

Option 3 involves major infrastructure redevelopment, and could include the potential removal of lineside signals once all rolling stock with access rights to the line is equipped with ETCS on-board. The ETCS system is likely to require infrastructure upgrades, particularly with regarding to the interlocking's and the interface to the Radio Block Centre. However, given that currently Solid State Interlocking (SSI) are not compatible with Radio Based Communications it is expected that the current SSI interlocking's will require an interface module, or replacement with a compatible CBI to support ETCS level 2.

The engineering and design of the system itself is likely to take a considerable amount of time. Additionally the fleet of rolling stock would have to be ETCS fitted in a short space of time. It is unlikely that this could be achieved by 2018 given that 68 vehicles would need fitting.

To effectively deliver the project a suitable migration strategy from the current ATP system to the ETCS system will have to be developed. Such a strategy will likely be complicated and require careful investigation and planning, before any design and development can take place.

It is presently the case there is not a great resource pool of expertise in the ETCS system, and this may present a challenge in the delivery of an ETCS solution. However, given the work presently under way on Great Western, this significance of this issue is likely to reduce. As with any application of ETCS, there will be the need to consider the logistics of equipping vehicles and infrastructure, not least as, at the moment, retrofitting ETCS equipment to vehicles is a significant challenge involving significant costs. Clearly, as the system is novel, the delivery would include a good deal of staff training. There are also significant HF issues associated with the Rolling Stock equipment; therefore train drivers will have to be adequately qualified to operate the ETCS fitted trains, which will need to be included in the considerations.

All of the installations and works carried out for Option 3 would, of course, be subject to regulatory approval, of which the exact processes for ETCS have yet to be completely determined for the UK. This complication presents further challenge to the scope of Option 3.

The reality is that acquiring a team of the size and competency required to deliver a project of such magnitude and complication, particularly with the timescale in question, is entirely unrealistic. Furthermore, the likelihood of the vast amount of funding required for such a venture being made available is undoubtably very small, if not completely negligible.

9.4 Option comparison

Table 9.1: Delivery Option Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
Supplier discontinuation of some components	Established technology	10-15 years life likely for electronics
Declining system knowledge base	Wide knowledge base	Regulatory Approval required
Lack of appetite from suppliers	Relatively simple to implement	1st in Class (FIC) testing
Levels of risk associated with alternative supplier	Regulatory Approve	Lack of resource to deliver

Key
Advantage
Disadvantage

10 Equipment Development Requirements/Risk

10.1 Option 1: SELCAB ATP Life Extension

As has been already noted above, the life extension option could avoid many of the issues arising from the other two options, and at least at a comparable if not lesser whole life cost than the other options, whilst at least maintaining present levels of safety and residual risk, and with a possibly higher level of certainty than the other options.

That is not to say that the technical challenges from any such approach are insignificant, and would clearly leave this isolated and unique example of SELCAB in situ until replaced by ETCS. The Atkins report has noted the many parallels between SELCAB (as implemented on Chiltern) and both LZB and Seltrac. The Atkins report has suggested the ability to use components from these systems adapted to achieve SLECAB functionality, and such an approach could avoid the substantial costs and safety risks from the TPWS option.

Discussions have been held with a contractor, Park Signalling, about their ability to 'reverse engineer' the system if they were to provide maintenance (in conjunction with or taking over from Thales) however it has not been possible to identify the costs without issuing Park Signalling with a Tender.

It is important when considering this option to ensure alternative suppliers have the capability to deliver support over the whole lifespan of the system. Knowledge base conservation and business security are two examples of considerations that should be analysed if utilising alternative supplier support is seriously considered.

10.2 Option 2: Deployment of Enhanced TPWS to Replace ATP

Scheme design would be needed to implement the TPWS system, and it is even possible that an entire scheme redesign may be needed should the current TPWS not comply with current legislation and safety requirements, or the levels of functionality needed to justify to the Safety Authority the turning off of the ATP system.

At the present time, it is not clear what level of fitment of TPWS would be needed to demonstrate under the provisions of the Common Safety Method that it is acceptably safe to justify the removal of ATP. Given the increased risks of SPADs that will arise with TPWS, and the higher levels of residual risk, demonstrating to an assessment body that the resultant controls will meet Common Safety Method requirements is going to be challenging.

10.3 Option 3: Accelerate Chiltern ETCS Deployment

Trackside

As ETCS is a relatively new technology, and as each application tends to be unique, significant development is required. This will involve the development of not only systems, but also national rules for approval and testing etc.

It could be expected that the trackside installation would be based on the principles established for the similar installation currently being carried out on Great Western (ETCS Level 2 with lineside signals). It is not presently clear, however, when the GW scheme will be sufficiently developed to enable those principles to be applied to Chiltern, leading to a need to keep the present ATP system operating until GW has progressed sufficiently. The main cost items are likely to include the provision of the Radio Block Centre, enhancements to the Infrastructure to provide sufficient GSM-R base stations and masts, and the installation of Eurobalise groups in accordance with the Class A specifications.

Rolling stock

The main challenges with this option are

- Planning the logistics of equipping the trains with ETCS, whilst maintaining functionality of existing train protection equipment
- Making enough space available in the cabs of the current rolling stock to accommodate the necessary controls, and in the vehicle for the on-board ETCS equipment.
- The ergonomics and human factors (HF) issues arising from installing the DMI when remodelling the cab, although again, it is likely that the GW scheme will provide some precedents that can be drawn on.

It may also theoretically possible to implement a solution using a Specific Transmission Module (STM)/European Transmission Module (ETM) which interfaces the on-board ETCS system with the current ATP system, to allow for a smoother migration. However this would require detailed system knowledge and therefore considerable investigation as to system operation. This incurs the same complications as would be encountered for Option 1 with an alternative supplier reverse engineering the system.

10.4 Option comparison

Table 10.1: Equipment Development Requirements Option Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
Components from other systems may be able to be used as replacement parts	Minimal development required	
No cost from alternative contractor for ‘reverse engineering’ option	Established technology	
Unclear on level of development required		Significant development required

Key
Advantage
Disadvantage

11 Regulation Requirements/Risk

The Railway Safety Regulations 1999 (RSR 99) required the installation of a form of train protection on the railway. The RSR 99 regulations were introduced to deal with safety risks highlighted by a series of accidents from trains passing signals at danger and collisions involving Mark 1 rolling stock.

Of relevance to the options under study under the Railway (Safety) Regulation 1999 are currently conditions that:

- A train operator must not operate a train without installing a train protection system and having it in service on that train;
- An infrastructure manager must not permit the operation of any train without a train protection system in service on the relevant railway.

Note that the term 'infrastructure controller' in RSR 99 stems from the Railways (Safety Case) Regulations 1994. This term now needs to be broadly interpreted under current legislation as an "Infrastructure Manager". However, under the Safety Directive (and hence ROGS) the IM only has a "Duty of Cooperation" (rather than any "permissioning" role) in relation to the operation of vehicles on infrastructure.

The existing railway fixed infrastructure is managed by Network Rail in accordance with the Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS) which came into force in 2006 (and was amended in 2011 and 2013). ROGS provides the regulatory regime for rail safety, including the mainline railway, metros (including London Underground), tramways, light rail and heritage railways.

The Regulations implement the European Railway Safety Directive (2004/49/EC), which provides a common approach to rail safety and supports the development of a single market for rail transport services in Europe. The following entities must comply with ROGS and have a duty to co-operate with one another:

- **Transport undertakings** - Any person or organisation that operates a vehicle in relation to any infrastructure.
- **Infrastructure managers** - Any person or organisation responsible for developing and maintaining infrastructure or for managing and operating a station and manages or uses that infrastructure or station or allows it to be used for the operation of a vehicle.
- **Transport Operator** - Any transport undertaking or infrastructure manager.
- **An 'Entity in Charge of Maintenance'** - Any person or organisation that is responsible for the safe maintenance of a vehicle and is registered as an ECM in the national vehicle register. This can include people or organisations such as transport undertakings, infrastructure managers, a keeper (usually the owner of a rail vehicle) or a maintenance organisation.

The ROGS regulations require each 'duty holder' ("Transport Operator") to maintain a Safety Management System (SMS) and hold a safety certificate (Railway Undertaking (RU)) or safety authorisation (Infrastructure Manager (IM)), indicating the SMS has been accepted by the Office of Rail Regulation (ORR).

The regulations require these transport operators to maintain a Safety Management System (SMS) and to hold a safety certificate (TU) or authorisation (IM), indicating the SMS has been accepted by the Office of Rail Regulation.

A list of Class B systems is established in the European Railway Agency technical document 'List of CCS Class B systems', ERA/TD/2011-11, version 1.0" - Clause 2.2 of 2012/88/EU. The document identifies 'Class B' systems allowed in case of renewal or upgrade in particular Member States. In addition to ETCS on-board (which is defined as the 'Class A' Train Protection system), AWS and TPWS are 'Class B' systems and may also be requested on-board vehicles. The Chiltern ATP System has not been notified by the UK Member State as a 'Class B' system and therefore cannot be requested on board in accordance with TSI 2012/88/EU, or under TSI provisions enforced under ROGS Regulation 5.

Network Rail maintains and develops the main line infrastructure and has arrangements in place, via their Safety Management System, to control the safety of new or changed infrastructure before it is placed in service, including where such projects are deemed significant under the CSM REA.

As an RU, Chiltern Railways operate the vehicles on the main line infrastructure and has arrangements in place, via their Safety Management System, to control the safety of new or changed vehicles before being placed in service, including where such projects are deemed significant under the CSM REA.

These SMS arrangements for Chiltern Railways are to be noted in Appendix C2 of this report.(Note: At the time of this report, no information has actually been provided by Chiltern Railway to their SMS arrangements).

In addition, Article 2(2) of the EC Decision requires that "Member States shall ensure that the functionality, performance and interfaces of the Class B systems remain as currently specified, except where modifications are needed to mitigate safety-related flaws in those systems" and there is also a requirement in Clause 7.2.3 of the related TSI that "the Member State shall make every effort to ensure the availability of an external Specific Transmission Module (STM) for its legacy Class B train protection system or systems".

The Chiltern ATP System does not appear in European Railway Agency (ERA) list of Class B systems (being "a limited set of train protection legacy control-command and signalling systems that were in use before 20 April 2001) for use in the UK. The SELCAB system may therefore not be requested as an on-board system on new rolling stock (or rolling stock that is upgraded) to run on a given line (Article 2.1 of 2012/88/EU) such as the line from Marylebone to Banbury via Aynho Junction which is a conventional Trans European Network (TEN). The provisions of the TSI do not apply to those sections of the Metropolitan Line over which Chiltern Trains are permitted to operate, and as such, that is a discussion between Chiltern Railways and LUL (under the ROGS duty of co-operation).

A contrary situation exists regarding the GWML ATP installation (which is a Class B system and does appear on the ERA list) where there is a view of both NR and the TOC (and possibly the ORR) that where ATP is fitted, it will require to be maintained until ERTMS and its subsystems is installed, so it can be replaced with an equivalent provision.

11.1 Option 1: SELCAB ATP Life Extension

In general terms, ATP equipment is designed to meet Safety Integrity Level 2 (SIL2) as defined in IEC60158.

As an ATP system, SELCAB meets one of the definitions of a train protection system in the Railways (Safety) Regulations 1999, which states “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.”

There challenge faced by Option 1 in terms of adhering to regulation requirements is minimal, and therefore presents very little concern in this aspect.

11.2 Option 2: Deployment of Enhanced TPWS to Replace ATP

TPWS has no SIL rating as defined in IEC 60158.Compliance with current regulations is likely to be the biggest challenge in the face of the application of TPWS, dispensation is required from RSR99 would need to be granted (by ORR) for Chiltern Line to regress from ATP to TPWS.

Some trains on the Chiltern Network require access to LU infrastructure and it is a LU requirement that any rolling stock operating on their network is fitted with roll back protection. This requirement poses a challenge because there is no inherent roll back protection with TPWS.

Not only does a proposal to replace the Chilterns ATP system with TPWS or ETCS have the potential to affect the safety of the railway, but even if it does not change the performance of the railway, it will be considered “major” renewal work as defined in RIR 2013. As such, it is possible that any such substitution work would require “authorisation to place in service” from the Safety Authority under the provisions of the Railways (Interoperability) Regulations before such a solution is “put into use”.

Dispensation would need to be granted from the ORR for the Chiltern Line to change from ATP to TPWS. To support an application for approval of Option 2, it is likely that a Signal Overrun Risk Assessment Tool (SORAT) assessment be completed for every signal, to demonstrate that the system provides adequate safety protection.

Whichever route is selected, both Network Rail and Chiltern Railways will need to prepare an evaluation and assessment for their respective parts of the transport system (i.e. at least Control Command and Signalling (Trackside) Subsystem CCT for Network Rail, and Control Command and Signalling (On-board) Subsystem CCO for Chiltern Railways).

However, as there is no known and equivalent system to Option 2c (using TPWS to mimic ATP functionality) operating in the same application circumstances and having reviewed the requirements in the CSM-REA for a ‘reference system’, it is far from certain whether the reference system route would, in practice, be viable. Further work, required to determine the feasibility of this approach, is considered to be beyond the scope of this report.

The other definition for a train protection system in the Railways Safety Regulations is “(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”. It can be seen therefore that there is a clear distinction in the regulations between a train protection system which controls the extent to which a signal is passed at danger (TPWS), or controls the risk of a signal actually being passed at danger (ATP), and this important distinction will need to be considered in ascertaining the way forward.

The statutory requirement for TPWS at speed restrictions in the Railways (Safety) Regulations is as follows:

‘Where there is a speed restriction if– (i) the permitted speed on that approach is 60 miles per hour or more; and (ii) in order to comply with the restriction, a train travelling at the permitted speed on that approach would need to have its speed reduced by one third or more. This corresponds to the location where an Advanced Warning of Speed Restriction indicator would be provided at the lineside. The regulations recognise the limitations of TPWS for over speed management, and limit them to this single situation.’ (The Railway Regulations 1999, 1999)

11.3 Option 3: Accelerate Chiltern ETCS Deployment

ETCS is the Train Protection part of the European signalling solution and will fulfil the requirements set out in the Railway Safety Regulations 1999, ROGS (ROGS), Vehicles Risk assessments as well as European Directives and secondary legislation.

Any major upgrade to the signalling infrastructure will be according to the Interoperability Directive, which is enacted through the Railways (Interoperability) Regulations 2011 (RIR) in the UK. This legislation came into force on 16 January 2012 and implements the EC Directive 2008/57/EC on the interoperability of the rail system in the UK. All mainline railway systems are subject to the Interoperability Regulations. The regulations apply to new, major, upgraded or renewed infrastructure and rolling stock and applicants for authorisation have to follow a formal approvals framework and seek an authorisation from the ORR, to place the infrastructure or rolling stock into service.

The Interoperability Directive 2008/57/EC has subsequent amendments which, since 2012, cause the verification procedure for subsystems to split in two parts; an EC verification procedure by a Notified Body and a 'verification procedure in the case of national rules' by a Designated Body.

The amendment also split the Control-Command and Signalling subsystem into two new subsystems; trackside CCS (CCT) and on-board CCS (CCO), each of which can be 'authorised' independently.

The interoperability Regulations do not apply to LU controlled infrastructure.

11.4 Option comparison

Table 11.1: Regulations Requirements Option Comparison

Option 1: SELCAB ATP Life Extension		Option 2: Deployment of Enhanced TPWS to Replace ATP		Option 3: Accelerate Chiltern ETCS Deployment	
Trackside	**Trainborne**	**Trackside**	**Trainborne**	**Trackside**	**Trainborne**
HS&WA	HS&WA	HS&WA	HS&WA	HS&WA	HS&WA
ROGS 2013	ROGS 2013	ROGS 2013	ROGS 2013	ROGS 2013	ROGS 2013
		RIR 2011 Reg 13 (disapplication of Authorisation)	RIR 2011 Reg 13 (upgrade onboard to Mk3 or Mk4) (disapplication of Authorisation)	RIR 2011 (Authorisation)	RIR 2011 (Authorisation)
		RSR99 dispensation	RSR99 dispensation	CCS TSI ERTMS / ETCS Trackside	CCS TSI ERTMS / ETCS Onboard
				Alter CP5 / CP6 agreement	Alter Franchise Conditions

KEY:
Complex
Less Complex
Common Practice
Not complex but not common practice

12 Approval Requirements/Risk

The key factor in addressing the approval issue is how the "reasonably practicable" justification is made for the course of action to be taken, that meets the requirements of the Railways (Safety) regulations 1999, the ROGS regulations (2006) – as amended particularly in 2013 [abolition of safety verification for main line railway] and the Interoperability Regulations (2011) (delivered through conformity with TSI's) such that:

- Compliance is achieved with the NR system for management of change,
- The selected option receives a positive safety assessment report under the relevant provisions of the Common Safety Methods
- Neither NR or a TOC or FOC would be subject to enforcement action,
- The course of action upholds the legal responsibility for safe operation of the transport system allocated separately to duty of co-operation between Infrastructure Managers and Railway Undertakings, and the duty of co-operation between them,
- In the unfortunate and unlikely event of an accident arising in consequence of the decision, provides a defence in Law for what has been done.

12.1 Option 1: SELCAB ATP Life Extension

Any project that creates a change to the fixed infrastructure managed by Network Rail requires to be agreed and the change managed in accordance with the NR H&SMS. This implies that a submission will need to be prepared according to the Project Advice Note (PAN081) guidance and will need to be agreed and endorsed by Network Rail Approvals Panel (NRAP).

System re-approval may be required, the VOBC is not particularly complicated (an embedded 8-bit 80188 dual processor system running 8086 based instruction set) and similar modern embedded systems exist (e.g. PC/104 architecture utilising processors with the 8086 instruction set). However, re-engineering the system would force revaluation of the system to current standards i.e. formal construction of the software, extensive verification and validation of the system from software module level up to full system test for a system required to meet a high SIL level. It is the extensive development and V&V process for something which has a limited application (124 cabs total) which renders the task unfeasible.

If the system is deemed to be obsolete and unmaintainable, it will be non-compliant with future legal requirements for maintenance planning and may then be considered to be in breach of the law.

12.2 Option 2: Deployment of Enhanced TPWS to Replace ATP

A meeting between Network Rail and ORR on 8th October 2014 discussed some likely project approval implications and risks. The minutes are somewhat silent on the practicalities, but the justification may involve each party either

a) submitting an explicit risk estimation under the CSM (402/2013 Annex I 2.1.4 (c)) demonstrating how the outcomes in CSM Annex I section 2.5 are met by the proposal, including the criterion at CSM (402/2013, Annex I. 2.5.4) i.e. "For technical systems where a functional failure has a credible direct potential for a catastrophic consequence, the associated risk does not have to be reduced further if the rate of that failure is less than or equal to 10^{-9} per operating hour.", or

b) using the ATP installation as a “reference system”, and then demonstrating how the design of the substitute system based on TPWS demonstrates equivalence with the existing ATP system

Both Network Rail and Chiltern Railways would need to do this for their respective parts of the train protection system (i.e. trackside for Network Rail, train-borne for Chiltern Railways).

There is the possible risk of a circular argument arising. A reading of the CCS TSI suggests that it would not be inconsistent with TSI requirements to remove signalling systems which are neither Class A nor Class B as defined in the TSI. However, this process would seem to be inconsistent with the Railways Safety Regulations (RSR99), which do not seem to provide a path to regress from ATP (once decided that it is not “reasonably practicable” to install it) back to TPWS. This would therefore require a legal dispensation from RIR99 (as was referred to in the minutes of the NR/ORR meeting). It is likely, however, that this dispensation would be granted since the DfT have granted dispensation to projects under similar circumstances to that facing the Chiltern railway (see Appendix F).

The Network Rail Management System Chapter 3.5 (Network Rail Health and Safety) suggests current TPWS implementation may provide a sufficient level of protection for the railway. However, the justification for the replacement of the existing ATP system with a system of lower safety integrity, and with the potential to lead to an increase in SPADS, will need careful consideration when making the arguments under the CSM to the appointed Assessment Body. Methodologies would need to be developed to ensure that NR and Chiltern Railways can both be satisfied that the trackside and train-borne equipment remains within the description of the specification documents and compatibility case.

To support an application for approval of TPWS, it is likely that, at least as a minimum, a Signal Overrun Risk Assessment Tool (SORAT) assessment would be required for every signal.

As the application rules for enhanced TPWS are currently not “notified”, and there are no TPWS standards provided for in TSI’s, it would not, in reality, be possible to carry out any form of verification process in accordance with the Regulations. It therefore seems likely that any proposal to replace ATP with TPWS should be the subject of an application to the UK Member State to determine that authorisation is not required under Regulation 13.

With regards to system specifics, the trainborne TPWS Mk 3 is not specified by Group Standard, but has been developed by Thales as a form, fit and function replacement as parts of TPWS Mk 1 have become obsolete, it is an undated version of TPWS Mk 1 which has also included addressing the key risk in TPWS Mk 1 of “reset and continue”. Before the adoption of TPWS Mk 3, Discussions with approval bodies are required in regards to derogations, or to decide if compliance with GE/RT8075 forces adoption of TPWS Mk 4.

Any re-engineered on-board equipment will need to be compliant with current standards (e.g. EMC electronic equipment etc). This may not be a trivial matter as new installations will be required to operate and interface with the older equipment which may not conform to the current standards.

Option 2 will require the appointment of an Assessment Body (AsBo) to carry out independent assessment and approval of the new system.

12.3 Option 3: Accelerate Chiltern ETCS Deployment

The Contracting Entity (Network Rail) would need to obtain subsystem verification (by a Notified Body). This would confirm that the design of the system to be deployed was in provided in conformity with the Technical Specification for Interoperability and the associated rules. The Notified Body would provide statutory surveillance during the full duration of the project works, and the Contracting Entity would then seek Authorisation for Placing into Service' (APiS) from the ORR.

Option 3 will require the appointment of an Assessment Body (AsBo) and a Designated Body (DeBo) to carry out independent assessment and approval of the new system.

12.4 Option comparison

Table 12.1: Approval requirements option comparison

Option 1 Life Extend		Option 2 TPWS (etc)		Option 3 (ERTMS/ETCS)	
Trackside	Trainborne	Trackside	Trainborne	Trackside	Trainborne
		CSM AsBo Assessment	CSM AsBo Assessment	CSM AsBo Assessment	CSM AsBo Assessment
CSM Assessment - Revised Maintenance Standards	CSM Assessment - Revised Maintenance Standards				
		RSR99 dispensation (ATP not energised)	RSR99 dispensation (ATP not functional)		
				NoBo Assessment (TSI CCT)	NoBo Assessment (TSI CCO)
		DeBo Assessment (NNTR e.g. GE/RT/8075)	DeBo Assessment (NNTR e.g. GE/RT/8075)		DeBo Assessment (Open Points e.g. DMI)
					NoBo Assessment (TSI LOC/PAS)
				Authorisation for Placing in Service (ORR - CCT)	Authorisation for Placing in Service (ORR - CCO; LOC/PAS)
		Track Access (Network Code)	Track Access (Network Code)	Track Access (Network Code)	Track Access (Network Code)
		Alter Licence Conditions	Alter Licence Conditions	Alter Licence Conditions	Alter Licence Conditions
GE / RT / 8270 compatibility case	GE / RT / 8270 compatibility case	GE / RT / 8270 compatibility case	GE / RT / 8270 compatibility case	GE / RT / 8270 compatibility case	GE / RT / 8270 compatibility case
NR Safety Management System	Chiltern Safety Management System	NR Safety Management System	Chiltern Safety Management System	NR Safety Management System	Chiltern Safety Management System

KEY:
Common Practice
Less Complex
Complex

13 Reliability

13.1 Option 1: SELCAB ATP Life Extension

Equipment obsolescence, aging and degradation will obviously have an impact on system reliability. The Atkins report (2011) highlighted a number of high risk components in the system. As the current SELCAB ATP is deemed to be obsolete, it can be expected that, in accordance with the 'Bath Tub curve' of product failure behaviour, the SELCAB ATP would experience increasing failure rates over the duration of the life extension. This trend appears to be supported by data available of delays and cancellations caused by ATP (and TPWS) failures, in Figures 13.1, 13.2 and 13.3.

Figure 13.1 in particular gives a clear indication of the scale of the impact of the failures of ATP, and thus the evident unreliability of the current SELCAB arrangement. Although there was only a 3% increase in delay minutes from 2013 to 2014 caused by ATP failure, the number of cancellations and Public Performance Measure (PPM) failures that resulted from ATP failure was substantially more in 2014 than in 2013 (both categories experienced over 100% increases from 2013 to 2014).

The unreliability of Option 1 therefore presents a serious level of systematic risk. It is only likely that the rate of ATP failures will increase unless a suitable mitigation strategy/solution is formulated. Drawing from the findings of Sections 5 (Integration Requirements) and 9 (Delivery), finding such a strategy/solution adequate to ensure sufficient Reliability would appear unlikely.

Figure 13.1: ATP/TPWS Delay Minutes

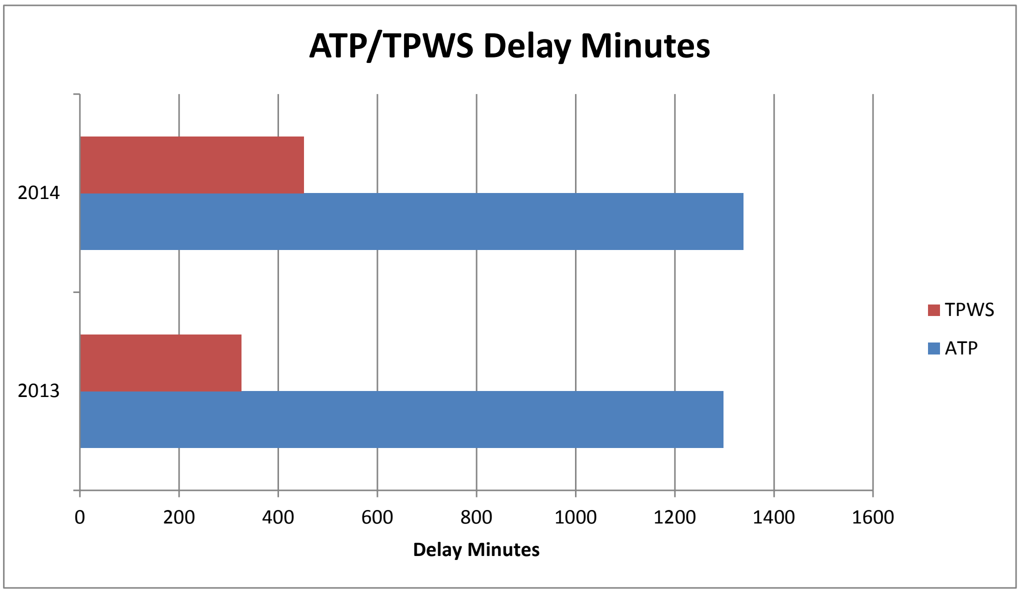
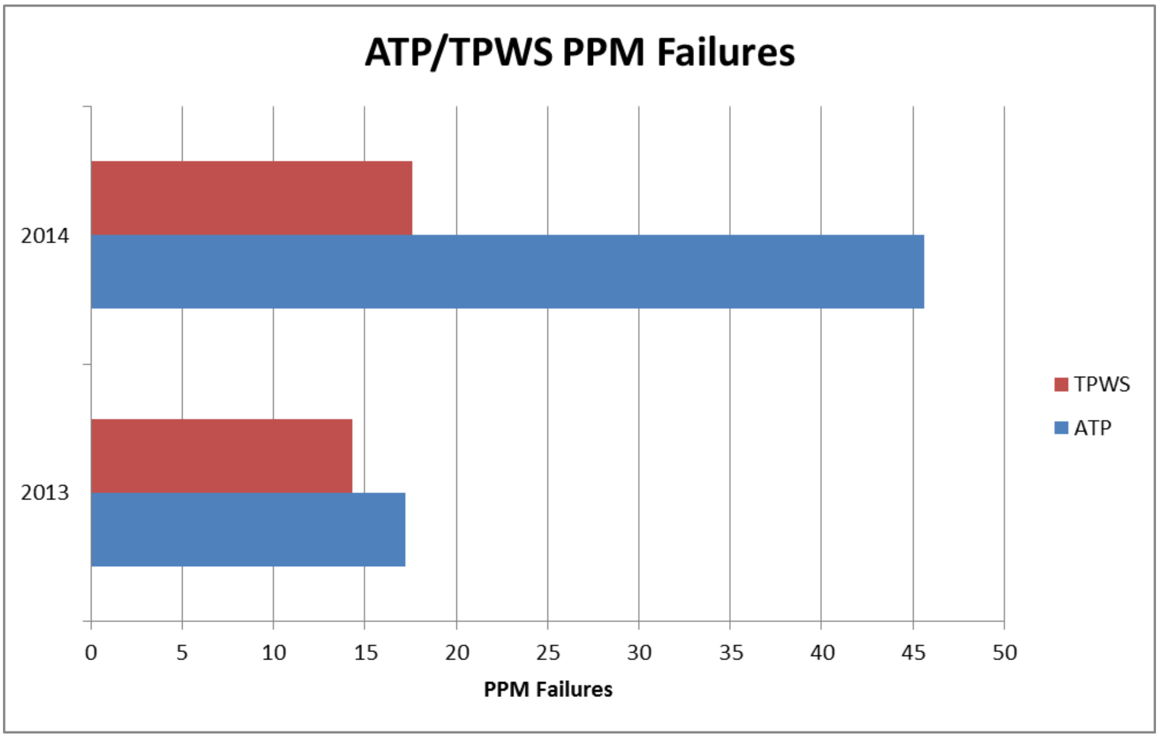
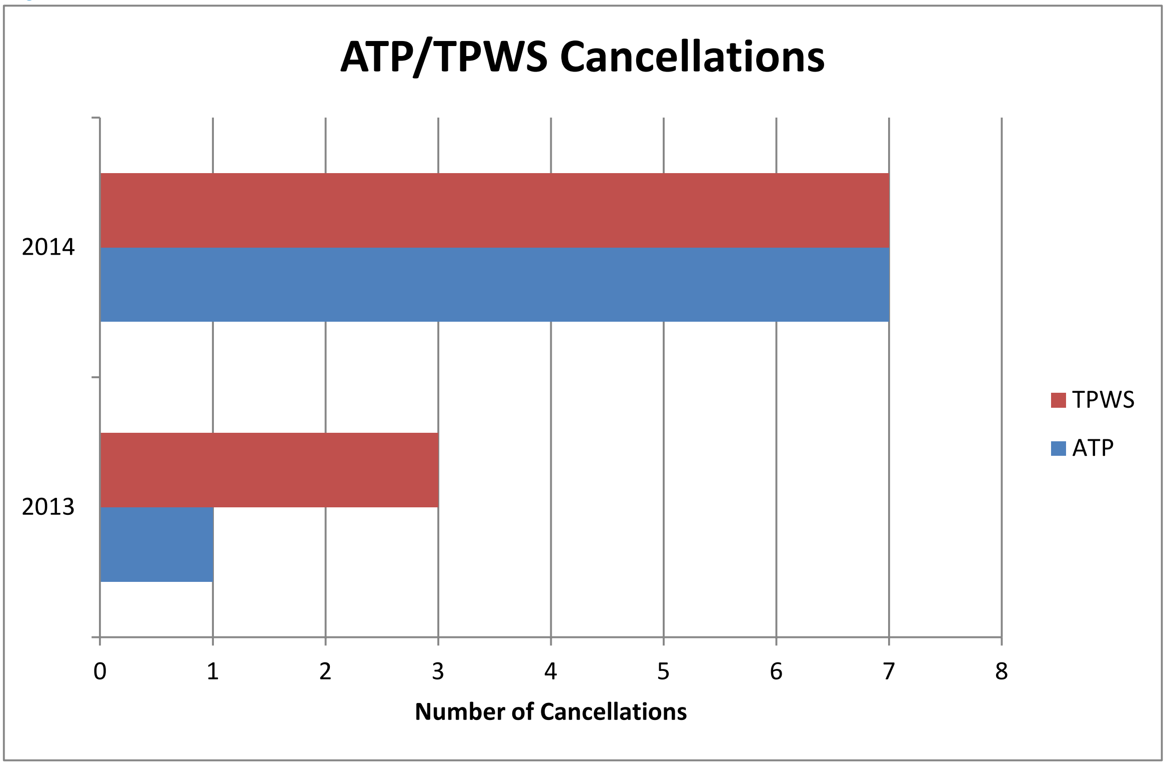


Figure 13.2: ATP/TPWS PPM Failures[3]



3 A PPM failure is a train that is five or more minutes late or was cancelled in some way (Pine, Calvin, FTS etc). The software used to calculate and allocate the level of responsibility of a PPM failure to a specific cause using various algoritms. If one train is cancelled due to incident A and two trains are sufficiently delayed by that they fail PPM then the incident is declared to have caused 3 PPM failures. If on the other hand one of those delayed trains had lost 3 minutes to incident A and another three to incident B then Incident A caused 2.5PPM failures and incident B caused 0.5 PPM failures.

Figure 13.3: ATP/TPWS Cancellations



13.2 Option 2: Deployment of Enhanced TPWS to Replace ATP

The primary functionality challenges that have faced TPWS in its history, such as aerial harnesses, connectors and output relay contacts have been identified and resolved. TPWS has had over a decade of successful operation in the UK and therefore can be deemed well proved and reliable.

Option 2 will offer an improvement to the Chiltern Railway reliability as by removing the ATP system it means there is one less system capable of disrupting the railway service.

However concerns have been raised by the increasing rate of failure of TPWS loops and modules. As can be seen from the Figures 13.1, 13.2 and 13.3, the number of delay minutes caused by TPWS failure increased by 39% from 2013 to 2014, with a total of 7 cancellations in 2014 as opposed to 1 in 2013 caused by TPWS failure. This trend has been confirmed by the principal maintenance engineer, who has indicated considerable concern over the reliability of the TPWS installed on the line. He was quoted in a telephone interview stating: "TPWS which 18 months ago was my most reliable asset, is now my least reliable asset". He also stated that TPWS was beginning to become more expensive to maintain than ATP, though no figures have been able to be sourced to back this up.

The evident lack of reliability of the current TPWS installation and the level it concern it presents would suggest, therefore, that if Option 2 were selected the current TPWS would likely have to be replaced regardless of the chosen configuration.

13.3 Option 3: Accelerate Chiltern ETCS Deployment

The system is relatively unproven given that the system is not widely implemented across Europe. Lessons can presumably be learned from the Cambrian Line ETCS rollout, however other than this and the other current European applications (for which limited information to do with reliability is currently available), it is difficult to make a true assessment as to the overall reliability of the system.

13.4 Option comparison

Table 13.1: Reliability Option Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
ATP delays make a notable contribution to delays	TPWS is experiencing an increasing number of failures. Will likely need replacing.	
	Well proved, reliable system	Not widely implemented, level of reliability relatively relatively unknown
	Removes surplus system	

Key
Advantage
Disadvantage

14 Operational Performance

14.1 Option 1: SELCAB ATP Life Extension

The ATP induction loops provide the operational benefit of offering a protection infill to the train and a release speed to the driver. This reduces unnecessary braking as the system informs the train when formerly restrictive signal aspects have improved to a ‘proceed aspect’.

TSR functionality is available with SELCAB, albeit not particularly easy to implement as this requires EPROM programming and manual installation of the EPROM at the relevant LEU(s).

14.2 Option 2: Deployment of Enhanced TPWS to Replace ATP

The replacement of ATP with TPWS removes the nuisance ‘false alarm’ ATP events which can occur on the current ATP system.

Staff training will be simplified as the system is already well known by staff across the network as the system is so widely implemented.

There is the potential for a negative capacity/performance impact, whereby a train is tripped by the speed trap, and the signal previously at red improves to a non-restrictive aspect, journey time is increased as the train has to come to a stop before restarting to proceed.

Some trains on the Chiltern Network require access to LU infrastructure and it is an LU requirement that any rolling stock operating on their network is fitted with roll back protection. This requirement poses a challenge for Option 2, where there is no inherent roll back protection with TPWS.

14.3 Option 3: Accelerate Chiltern ETCS Deployment

Level 2 offers a potential increase in capacity, as the close level of continuous supervision allows for an efficient run of service.

However the introduction of a new system will require drivers to become accustomed to the new system, new DMI, equipment and different driving styles, all of which means additional human factor training interventions.

14.4 Option comparison

Table 14.1: Operational Option Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
Infill and release speed improves capacity/performance	Potential negative capacity/performance impact	Potential increase in capacity/performance
TSR functionality		TSR functionality
	Simplified staff training	Staff training required
	Removes 'false alarm' ATP events	

Key
Advantage
Disadvantage

15 Maintainability

15.1 Option 1: SELCAB ATP Life Extension

As previously mentioned, availability of some components are becoming difficult or impossible to source with suppliers discontinuing their production. For some of these cases it is thought that no alternative supply source will be available for obsolete sub components. In particular, Chiltern are approaching the point at which the global supply EPROMs will be exhausted.

Additionally the declining SELCAB system knowledge base is also a factor that will impact the maintainability of the system.

15.2 Option 2: Deployment of Enhanced TPWS to Replace ATP

TPWS equipment and expertise is widely available in the UK, and is likely to continue to be for the foreseeable future.

However, Chiltern TPWS has experienced an increase in failure rates in the last 18 months, to the point where the maintenance engineer responsible for Chiltern described TPWS as his ‘least reliable asset’.

Option 2c, TPWS with ATP equivalent functionality, has the potential to present a more serious concern in terms of maintainability. This is because Option 2c involves the installation of more TPWS equipment than would be expected for a standard TPWS installation, and therefore there is more equipment to experience faults. If, as may be the case, 16 loops are installed per signal (8 times as many as would usually be expected), it is conceivable that maintenance costs and demand are likely to be 8 times as much as a typical TPWS installation.

15.3 Option 3: Accelerate Chiltern ETCS Deployment

The system is new and therefore there is not a wide availability of expertise and knowledge of the system. Therefore training would be needed to get staff proficient in carrying out maintenance.

Chiltern also have extensive depot diagnostic, testing and to a limited extent repair facilities for the SELCAB equipment, probably to a much greater degree than would be the case with new ETCS equipment. Thus with option 3 Chiltern may be forced into a regime of sending equipment back to suppliers and waiting for the supply of spares to address some faults which at present Chiltern can resolve directly in the depot ATP workshop.

15.4 Option comparison

Table 15.1: Maintainability Option Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
Difficulty sourcing components	Equipment widely available	
Declining knowledge base	Well known system	New system, expertise not widely available

Key
Advantage
Disadvantage

16 Human Factors

16.1 Discipline Areas

For each option, the following areas were investigated from a Human Factors stand point:

i. In-cab layout
ii. Driver workload
iii. Driver training
iv. Impact on operations (SPAD).

16.1.1 In-cab Layout

The train cab is a very specific work environment. Display/control layout, noise, atmospheric variables can significantly affect the driver and the task that they perform. Developing a cab layout that best assists the driver to complete these tasks in the safest and most efficient manner is extremely important. For each option, the introduction and/or replacement of equipment or displays/controls was assessed to determine the suitability of the proposed layout. Similarly any alterations to the cab layout will involve consultation with the driver union ASLEF (Associated Society of Locomotive Engineers and Fireman).

16.1.2 Driver Workload

Any task activity that has to be performed by the driver will have an associated impact on their workload, both physical (e.g. number of controls/buttons to be pressed or displays to be viewed) and cognitive (e.g. interpretation of incoming data and decision-making requirements). Each of the three options will produce a different workload that the driver will experience.

Humans have different pools of resources to process information; visual/auditory/tactual input, perception, processing and actions, as well as subconscious/symbolic/linguistic reasoning. Depending on the nature of the task; if the tasks require the same pool of resources or if the task requires different resources, these resources may have to process information sequentially or can be processed in parallel. In the case of train driving, if a driver needs to complete two or more tasks that require a single resource e.g. receiving two or more auditory alerts, it could cause an excess workload which could lead to an increase in driver error or slower task performance.

For the three options, detailed workload assessments such as route driveability for the Chiltern line have not been carried out. However, each option has been generally assessed based on the perceived information input that would require processing by the driver.

16.1.3 Driver Training

The need for train crew and maintenance staff re-training or new training will vary for each option. Modernising the cab environment, whether it is simply updating old equipment or introducing new equipment to the driver desk will mean that the driver must be trained in order to use the equipment safely and to ensure the information provided to them is effectively processed. Similarly, any change/update to track infrastructure and the rolling stock will require maintenance, of which maintenance crew will need training for.

Furthermore, any updates or enhancements to current systems will require training on changes to operational principles and driving standards. In the case of ETCS, the introduction of the new system and technology will require training for new additional rules and procedures.

16.1.4 Impact on Operations- Signals Passed at Danger

Each option shall be assessed for the impact that SPADs have on operations, in addition to the impact on the driver and human performance. It is relatively easy to calculate the physical effect of a SPAD, while it is not so easy to assess the psychological impact. In addition, the effect of the protection systems and how they are designed to reduce the potential for a SPAD to occur will have an impact on the driver. The reporting of SPAD occurrences, as well as how they are prevented should the driver fail to stop at a red signal, is assessed for each option.

16.2 Option 1: Selcab ATP Life Extension

16.2.1 In-Cab Layout

Maintaining the existing ATP equipment wouldn't have an impact on the in-cab environment for the driver as it is not expected that any equipment, displays or controls would be replaced or added to the driver desk.

16.2.2 Driver Workload

As option 1 maintains ATP and Chiltern have not been able to suppress the AWS and TPWS when the ATP is operational, auditory alerts from all three systems will be provided to the driver. Shortly before a signal, the driver will be provided with both auditory and visual information from the AWS and potentially a auditory alert from the TPWS (if a SPAD occurs). Depending on the status of the signal or train speed, an acknowledgment from the driver may be required. Although there may be multiple visual tasks requiring perception and processing by the driver, especially as they are from symbols and not linguistic alerts, the workload remains at an acceptable level. In addition, the performance and potential for human error would remain at the level it is currently at, with no possibility of being reduced.

16.2.3 Training

Maintaining the current ATP system would require very little or no training. There may be some training required depending on the TSR functionality and current usage. If it is provided and currently used, there would be no need for additional training. However, if it is available and not currently used and the intention is to mandate it, further training may be required.

16.2.4 Impact on Operations- Signals Passed at Danger

With the ATP system maintained for this option, risk of SPAD is reduced as the as the ATP system aims to emergency stop the train before the signal. It is understood that if the brakes need applying automatically to the train, the incident is captured by the system for downloading post journey. If this is not completed the result is that incidents are not reported. From a human behaviour point of view, the driver understands the system is fail safe and is familiar with the actions of the ATP system in the event of overspeed towards a danger signal.

16.3 Option 2: Deployment of Enhanced TPWS to Replace ATP

16.3.1 In-Cab Layout

Removing the current ATP speed display and replacing it with a new one as part of the updated TPWS would also cause minimal impact to the in cab layout.

16.3.2 Driver Workload

Removing ATP and updating TPWS will mean the driver will only receive auditory alerts from the AWS and TPWS systems. This would create a reduced workload and providing the workload was not low originally, an increase in performance and reduction in potential for human error might be experienced.

16.3.3 Training

It is anticipated that any training requirements would be simplified for train and maintenance crew due to the upgraded TPWS system. However, removal of the ATP system and added safety features inherent to the familiar yet upgraded TPWS system may mean an adaptation to the driving style which would require updated driver training. While it is not fully understood the effect of the enhanced TPWS replacing ATP will have on driving style, it is anticipated their route knowledge may reduce due to the removal of the ATP speed display Other possible amendments to driving style cannot be suggested with any certainty unless a full Human Factors assessment and training model has been completed

16.3.4 Impact on Operations- Signals Passed at Danger

The removal of ATP would mean that approaches to signals would be monitored by the TPWS system. Although the TPWS system applies an emergency brake, the train will run into the overlap following the signal. The driver should then contact the signaller and the incident is reported. From a human factors point of view, there are a number of issues with the transition from moving from ATP to TPWS when relating to SPAD incidents, expanded below.

16.3.4.1 Human Behaviour

Drivers who run on TPWS only routes who are familiar with ATP systems could potentially be at a higher risk of loss of focus on the task, driver distraction or incorrect expectation, increasing the possibility of an incident occurring similar to the Didcot incident. It is understood that a run into an overlap that coincides with another junction is at Leamington Spa.

16.3.4.2 Situational Awareness

Rail Safety and Standards Board (RSSB) reported that route knowledge and the importance of situational awareness are key requirements for train driving (RSSB, 2006). With respect to transitioning from ATP to TPWS systems, the potential risk is that although drivers may have good route knowledge (static element), the application of knowledge to correctly comprehend a situation and implement appropriate actions (dynamic element) may be reduced due to the familiarity of the ATP system. If this occurs, the potential for running past the danger signal into an overlap increases, as the driver may be expecting the system to stop them (as the ATP would have done) prior to a red signal. Having complete situational awareness, comprising of good static and dynamic elements, is essential in reducing the risk of SPADs and possible risks from occurring.

16.4 Option 3: Accelerate Chiltern ETCS Deployment

16.4.1 In-Cab Layout

Introducing the ETCS DMI to the driver desk in terms of physicality of layout should not present too much of a challenge since the desk on the Chiltern rolling stock are quite large. When implementing the ETCS DMI, the current speedometers would be removed and the available space on the desks could accommodate any required relocation of AWS/TPWS displays and controls.

As it is suggested the driver desks can accommodate the DMI, there should be no issues regarding driver anthropometrics and reach distances to the touch screen interface. However, including a DMI to a train cab environment presents issues such as glare, both direct and indirect. Similarly, the varying amount of light entering the cab, for example going through a tunnel, as the change of light reflecting onto the DMI will influence the readability of the information presented. Research in this area has been carried out by RSSB explaining the risks associated and possible mitigations.

As a note of caution however, without a formal assessment, the suggestions are based on cab photos (Figure 5.1) and a subjective visual assessment from Mott MacDonald's Principal Rolling Stock Engineer.

It is imperative that should option 3 be taken forward a full cab assessment, both physical and environmental, should be conducted to ensure the above suggestions are validated. This will need to include panel clearances, cable routing and maintenance access, and positioning of structural members to ensure a comprehensive review is completed. Location and angle of the DMI on the driver desks would require an assessment to ensure that the risks associated with glare are mitigated.

Figure 4: Current Chiltern rolling stock driver desks

16.4.2 Driver Workload

Fitting ETCS to the driver cab, especially during the overlap period migration of installation and decommissioning of ATP, will mean the driver will have five systems present in the cab: TPWS/AWS, GSM-R, Vigilance, ATP and ETCS. When the train is running on an ETCS fitted section of track, the alerts/alarms from TPWS, AWS and ATP will be supressed, leaving only those from ETCS, GSM-R and Vigilance. However, when the train then runs into a non-ETCS fitted section of track, those systems become operational and ETCS will not be. The driver will then be faced with the worst case scenario of alerts/alarms from four systems, in addition to having to process the decision that the alert has not been produced by the ETCS system. This additional decision making process, in addition to deciding which system the alarm came from, could all lead to an increase in driver workload as well as providing a distraction to the driver when dealing with an alarm..

In addition, as the DMI provides visual text messages for the driver and for ETCS Level 2, they may need to interpret multiple visual inputs from the DMI, such as speed supervision information, planning information and supplementary driving information This would create competing visual tasks and as the new task includes ‘linguistic’ text messages (as opposed to just a symbol) the driver will have to work harder to perceive, process and decide upon actioning the visual information. Workload, performance and potential for human error will be increased by the requirement to acknowledge alerts/alarms from multiple systems, in addition to interpreting which systems are currently operational and thus could produce an alarm, which will increase processing time and increasing the possibility of cognitive conflict.

However, when the migration to ETCS is complete, there shall be only sensory tasks to complete from three systems. When ETCS is operational and the TPWS and AWS systems are suppressed the visual information provided by the DMI would reduce the tasks completed by the driver and reduce the opportunity for task competition and cognitive conflict, reducing the workload, increasing performance and reducing the likelihood of human error.

The report on the level crossing incident on the Cambrian line (Department for Transport 2012), where driver workload was deemed a causal factor, demonstrates the risks of the driver being faced with multiple visual tasks at the same time. In this case, the driver was distracted by concentrating on the ETCS DMI while running a brake test and changing ERTMS mode. The incident further highlights the necessity to complete a driver formal task analysis, as this would have picked up the potential for task conflict. It is understood that as part of the ETCS implementation, Network Rail's Route Driveability Tool shall be used to assess driver workload, in addition to the need for a task analysis being completed.

16.4.3 Training

The changes to the role and duties of train drivers and all other staff caused by the implementation of ETCS on the Chiltern line would need to be reflected in the establishment of new competency standards and the requirements governing training.

To outline the scope of training require for implementation of ETCS, the following would all require either in driver, operations or infrastructure training:

- Drivers
- Train Control Installation Technicians
- Train Control Maintenance Technicians
- Track Side Workers
- Signallers
- Traction and Rolling Stock Technicians
- Outside Parties (ORR, BTP, Emergency Services etc.)

For drivers only, the impact of the new ETCS system would mean a big change to the current training requirements. Implementing such a novel system, both technologically and operationally, would mean a major reform to the training programme in terms of the following:

- New display and controls to be processed/acknowledged in the cab
- 'Head-down' driving style as opposed to 'head-up' driving style as in-cab signalling would replace line side signalling
- New demand placed on the driver by the increased focus on the in-cab DMI
- Revisions to existing driver competency and fitness standards may be required in relation to visual acuity, hearing, decision-making and computer skills
- Revised operational practices and processes for ETCS modes and written instructions.

16.4.3.1 Migration

An STM could theoretically be developed to allow ETCS on-board equipment to operate using ATP trackside infrastructure, however this is deemed to be unfeasible for the Chiltern line, for reasons detailed in Section 17.3. This, along with the migration between ATP to ETCS meaning transitions between the two systems along the route would mean an extensive training model would be required to mitigate the potential human errors associated with using multiple systems along a single route. Although this would obviously have to be achieved when ETCS is currently due to be implemented on the line in 2028, developing this model for an accelerated roll out may pose a challenge.

The optimum rate of training for the Chiltern line will need to be defined upon a realistic consideration of the delivery rate of ETCS fitted rolling stock. The two must be aligned to ensure that re-training is not required if there are delays between initial training and the trains entering service.

Bringing forward the implementation of ETCS would mean ensuring that driver training centres and simulator training, crucial in enabling practise in a full range of driving conditions, are available well in advance in order to teach drivers the philosophy of ETCS driving and to provide a suitable level of detail to ensure that a consistent and accurate mental model of how the system works can be developed.

16.4.3.2 Lessons Learned

Training lessons learned from the Cambrian (National Skills Academy, 2012) that would require adapting to the Chiltern line are as follows:

- Must consider human aspects of training and the behavioural changes required- most prominently for the drivers, but also required for signallers as well as maintenance staff
- Bringing forward the roll-out schedule for the Chiltern line would mean a re-alignment of the proposed training schedule to ensure avoidance of re-training
- Using a closed Cambrian line to train drivers on ETCS is not an option so it is anticipated that simulators would need to be used as a replacement
- Operational and engineering requirements must be considered together- the customer impact must also be considered
- The training must ensure that the ‘how’ is covered, as well as the ‘what’
- The lack of resources/skills to develop and deliver training must be considered prior to commencement.

16.4.4 Impact on Operations- Signals Passed at Danger

Introducing ETCS on the line would provide increased protection against SPADs compared with TPWS only, due to the continuous speed supervision provided by ETCS Level 2. Providing a level of protection through the two stages of intervention will additionally increase driver confidence in the system. In addition, the Juridical Recording Unit (JRU) will have the function available to record train data transmissions. While it is not yet understood exactly what data transmissions the JRU will record on ETCS Level 2, the possibility that it could record any occasion where a train approaches the end of movement authority over the speed permitted will ensure drivers are more vigilant when adhering to their speed supervision.

16.5 Option comparison

Table 16.1: Human Factors Option Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
Limited Human Factor impact	Increase likelihood of loss of focus/driver distraction	Increased driver workload
	Simplified driver training	Increased driver training

Key
Advantage
Disadvantage

(RSSB, 2006) (DfT, 2011) (The National Skills Academy: Railway Engineering, 2012)

17 Migration Issues

17.1 Option 1: SELCAB ATP Life Extension

Life extension of the current ATP will have no direct migration issues associated. However the implication is that the same migration issues that would be encountered in pursuing Option 3 would also face Option 1, just with a delay until 2028 when ETCS is due to be rolled out under the current strategy.

17.2 Option 2: Deployment of Enhanced TPWS to Replace ATP

Migration from ATP to TPWS alone could be done with relative ease, due to the fact that all rolling stock is TPWS fitted. Assuming the additional trackside TPWS units are able to be installed while the current ATP and TPWS systems are operational, then as soon as the trackside fitment is complete, the ATP system can simply be ‘switched off’ and removed.

With regards to the rolling stock, due to the fact that all rolling stock are already TPWS Mk 1 fitted, and that installation of Mk 3 is relatively easy, it is unlikely that rolling stock will cause any significant challenges to any migration strategy. The migration to a Mk 4 based design would however incur significant challenges as it is not designed a straight forward drop in system, it requires an entire new design of mounting and connection, hence Mk 4 has not been deemed a feasible upgrade. Mk 3 is instead the chosen on-board upgrade for Option 2.

17.3 Option 3: Accelerate Chiltern ETCS Deployment

Option 3 presents significant migration challenges. These challenges are primarily present due to the complexity and substantial cost of rolling stock fitment, which restricts the number of rolling stock that would be able to be fitted and the speed at which the fleet would be able to be fitted.

Where there are a large number of vehicles that use the Chiltern Railway, including freight, careful thought needs to be given to vehicles not fitted with the ETCS system travelling on track fitted with ETCS infrastructure. Obviously, it is impossible to fit all the vehicles that could possibly use the Chiltern Railway with ETCS immediately, installation of ETCS on ALL the relevant vehicles will take a significant length of time and, of course, money. There is currently an ETCS rolling stock fitment program, and significant alterations would have to be made to this to begin to facilitate ETCS on the Chiltern network.

Therefore a migration strategy has to be devised to ensure that the ETCS system can be implemented without impacting safety or capacity. Maintaining capacity would likely be at the expense of safety, whereby having non-ETCS trains with no train-protection travelling on ETCS infrastructure. On the other hand, maintaining safety would likely be at the expense of capacity, whereby access to the infrastructure would be given to ETCS-fitted vehicles.

However, the scope of ETCS includes levels and modes designed to aid in the process of system migration; in particular, Level 1, and the Limited Supervision mode. Level 1 has been used in a number of countries across Europe, and Level 1 Limited Supervision has been used most notably for the Swiss migration to ETCS. Level 1 is also planned as the migration strategy for the national roll-out of ERTMS in Denmark (Passau, 2014).

These approaches, however, would require Network Rail to reconsider the UK ETCS strategy, which currently only has the scope for implementation of Level 2.

ETCS migration can also be facilitated on the rolling stock side by installing ETCS and ATP systems in parallel, or in series using interface units such as STM's and ETM's. However, the development of these interface units would require in-depth understanding of the current ATP system operation, software and firmware which would take extensive investigation, and would most likely be prohibitively expensive.

It is understood that an STM developed for ETCS that recognises ATP is available but is not to be utilised on the Chiltern network. This, along with the migration between ATP to ETCS meaning transitions between the two systems along the route would mean an extensive training model would be required to mitigate the potential human errors associated with using multiple systems along a single route.

The optimum rate of training for the Chiltern line will need to be defined upon a realistic consideration of the delivery rate of ETCS fitted rolling stock. The two must be aligned to ensure that re-training is not required if there are delays between initial training and the trains entering service.

Bringing forward the implementation of ETCS would mean ensuring that driver training centres and simulator training, crucial in enabling practise in a full range of driving conditions, are available well in advance in order to teach drivers the philosophy of ETCS driving and to provide a suitable level of detail to ensure that a consistent and accurate mental model of how the system works can be developed.

It should also be considered that early roll out of ETCS on the Chiltern Line will delay ETCS rollout elsewhere on the network, and therefore could possibly result in increased safety risk level or obsolescence issues elsewhere on the network.

17.4 Option comparison

Table 17.1: Migration Option Comparison

Option 1: SELCAB ATP Life Extension	Option 2: Deployment of Enhanced TPWS to Replace ATP	Option 3: Accelerate Chiltern ETCS Deployment
No direct migration issues	Relatively easy	Very challenging
Migration issues to ETCS still to be encountered, only deferred to later date		
		Rolling stock fitment complex and very expensive
		Strategies to facilitate migration have been developed

Key
Advantage
Disadvantage

18 Conclusions

The report was compiled gathering a wide range of information from multiple primary and secondary sources and independent studies, contributions from numerous Mott MacDonald staff from multiple disciplines, and many staff from stakeholder companies. Drawing from this large pool of evidence and stakeholder engagement, this report presents a sufficiently thorough and comprehensive analysis of the three chosen options given the information available to date.

However, it must be noted that due mostly to the unknown stances of the regulatory bodies on some of the intricacies of the options, in addition to the difficulties in determining Network Rail's ability to deliver Option 3, an entirely exhaustive analysis would be impossible to achieve at this point in time. Additionally, as is clearly conveyed by this report, the implications of each of the options reviewed are profuse and expansive, resulting in the selection of the Chiltern interim train protection system not on the face of it having an obvious solution. Notwithstanding this however, this report does make the conclusions below, which are founded on the broad and profound foundation of evidence, which can hence forthwith be deemed to be sufficiently reliable to enact upon.

The optioneering, analysis and investigatory works detailed in this report sought to provide an extensive representation as to the plausibility, implications and consequences of utilising any one of the three selected options (as reviewed by the Chiltern Steering Group) for the interim Train Protection system on the Chiltern line.

As a result of the above optioneering, Option 2 was found to be the most viable option given; the current National Rail programme constraints; the deliverability of the system (within the specified timescales); the affordability and the fundamental fact that it will expeditiously bring an overall safety improvement when compared to the current situation. Although the selection of Option 2 will necessarily mandate early engagement with the regulators this would most certainly be the case for all of the three options under scrutiny. However it also is worthy of note that Option 3 may require far greater scrutiny from the regulatory bodies given the level of assessment required by RIR for ETCS, the process for which is still relatively new to the UK.

The selection of Option 2 as the most viable option also aids migration to ETCS and will thus facilitate a much smoother transition to the programmed installation of the new ETCS train protection system, as Chiltern will effectively require the same upgrade as the majority of other lines in the UK (from TPWS to ETCS Level 2). Given the current programme constraints, the overall cost of selecting Option 2 will be far less than accelerating the deployment of ETCS, as defined in Option 3 (even though Option 2 also includes an upgrade of trainborne equipment), which would encompass not utilising the existing assets to end of their whole life as defined in the current business case.

In considering Option 2 it was noted that TPWS is generally designed to supervise trains with a 12%g or at best 9%g braking capability and that there is still a proportion of trains operating on the network that cannot provide this level of braking capability. Currently all passenger trains operate with 9%g braking capability, however it is a relatively small proportion of the freight trains that cannot deliver the recommended level of braking performance. Additionally, no freight trains are currently fitted with ATP and therefore, given this evidence, an extended TPWS fitment on the Chiltern line as detailed in Option 2 would actually reduce this risk overall (Sotera, 2012).

Notwithstanding the above recommendation the client must be diligent in understanding that a detailed risk-based safety assessment including (but not limited to) SORAT assessments of every signal on the route must be carried out to determine if a viable Safety Case can be produced for Option 2. It should also be noted that Option 2 results in a significant change in the current system's functionality, including the loss of roll-back protection which is currently a requirement of all trains that run on LU infrastructure. (The latter is currently the subject of a risk based assessment between Chiltern Trains and London Underground). As for the remaining two options, there is no doubt that in terms of system safety, SPAD risk, over speed risk and legal compliance that Option 3 is the long term solution for deployment in the UK.

Although Option 3 is the overall long term solution for the UK, its early deployment is not feasible within the accelerated timescales. Despite Option 3 clearly bringing enhanced operational and safety benefits the current business case and deployment programme make this option non-preferred due to its installation being based on the life expiration of the existing assets. Therefore not adhering to the current deployment plan will mean that its early implementation is neither cost effective nor feasible. The logistical challenges that face Option 3 also cast considerable doubt over its feasibility. These include but are not limited to resource constraints, migration issues and human factors assessments which are inherent more so in this option, and thus lead to further substantial complications. These difficulties are additionally compounded by accelerating the deployment of Option 3 and the impact that this would have on the national rollout strategy. Early deployment of Option 3 would also require a lengthy, expensive and demanding development process that resources and time may not allow.

As the situation currently presents itself, the evaluation of which overall option was most suitable was reduced to the assessment of whether the logistical, programme, safety risk, financial and resource challenges that face Option 3 outweighed the logistical, programme, safety risk, financial resource and legal challenges faced by the deployment of Option 2.

Option 1 (Selcab ATP Life Extension) is the least recommended viable option. 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. The SELCAB ATP currently installed on the Chiltern line was implemented in 1990; originally intended as a pilot for a UK wide ATP rollout. This, of course, never came to fruition, but what remains on Chiltern today is a 'pilot' protection system that is 25 years old and evidently life expired. It is of little surprise that maintenance engineers have been experiencing difficulty sourcing replacements of a technology that is a quarter of a century in age.

In addition to the above optioneering, it is worth noting that further investigation will be necessary in order to determine how the planned electrification of the Chiltern railway will affect the chosen option. Should the electrification have a significant enough impact such that it means that the Train Protection in place would have to undergo substantial modification, it would be judicious to coordinate the electrification with the rollout of the preferred option. This approach would avoid any unnecessary additional expense and complication of Train Protection modifications incurred by the electrification works.

In summary and given the constraints presented, it is the professional opinion of Mott MacDonald that Option 2 is the most viable option. Notwithstanding this, these conclusions are dependent on the timescales as we currently understand them remaining consistent. Should the rollout of ETCS be legitimately brought forward at a programme level from 2028 to around 2020 for example, then the life extension of the existing equipment may prove to be the most judicious and cost effective option.

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Appendices

Appendix A. ATP/TPWS Comparison

Table A.1: ATP/TPWS Comparison

Signalling Features	Chiltern ATP	Standard TPWS (as per 10137)	TPWS 3 and all plain line signals fitted
Supervision	Train Trip – emergency brake application if signal passed at danger.	YES	YES
	Speed – Maximum Permitted speed for the line	NO	Potentially yes but would require continuous fitment along the line of TPWS loops to achieve some sort of speed supervision. This would not be using TPWS as intended and would impact upon non Chiltern trains stock using the line.
	PSR speed changes both increases and decreases are monitored and not implemented until either; the rear of the train has left the previous speed section, for increases in speed, OR is implemented immediately the front of the train enters the commencement point for reductions in speed. This includes turn out speed supervision.	Yes, but only for regulated PSR reductions in speed. Does not check speed on the approach to reductions which do not meet the fitment criteria or for low speed turnouts.	Yes, but only for regulated PSR reductions in speed Does not check speed on the approach to reductions which do not meet the fitment criteria or for low speed turnouts.
	TSR speed changes both increases and decreases are monitored and not implemented until the rear of the train has left the previous speed section.		NO
	Position Light Signal moves an arbitrary speed is imposed when the train is moving under the authority of a PLS.	NO	
	Shunting moves a fixed 20MPH speed is imposed during shunting moves. This is irrespective of any other speed criteria.		NO

Signalling Features	Chiltern ATP	Standard TPWS (as per 10137)	TPWS 3 and all plain line signals fitted
	SPD following a train trip an arbitrary maximum speed of 20MPH is imposed	NO NO NO	NO NO
	Braking to stop at – Signal at danger is the 3 signal away Signal at danger is the second signal away Signal at danger is the next signal	NO TPWS will bring a train to a stop within the Safe Overrun Distance (SOD). This is beyond the signal whereas ATP regulates the speed to bring the train to a stop before the signal at danger.	NO TPWS will bring a train to a stop within the Safe Overrun Distance (SOD). This is beyond the signal whereas ATP regulates the speed to bring the train to a stop before the signal at danger.
	Rolling Away – The train is monitored and proved to be stationary and not rolling backwards	NO	NO
	Signal Passed at danger (SPAD) Speed is calculated so that a train will stop within the O/L	YES Only for signal fitted as per 10137 and to stop within the SOD at 12% braking.	YES All signals presently fitted with ATP to be fitted with TPWS. The design of the new fitments could be made such that the train was brought to a stand within the O/L of the signal. To provide

Signalling Features	Chiltern ATP	Standard TPWS (as per 10137)	TPWS 3 and all plain line signals fitted
			a consistent TPWS fitment the existing TPWS should be reworked to ensure that the train was brought to a stand within the O/L of the signal. This would not be using TPWS as intended and would impact upon non Chiltern trains stock using the line. Potentially need to provide driver training to highlight the changes to driving style required or risk a potential increase in SPAD occurrences.

Appendix B. TPWS Cost Breakdown

Table B.1: TPWS Costings

Equipment	**Capex** (Midweek working/Possession working)	**Opex (10 years)** (Midweek working/Possession working)	**Total (WLC 10 years)** (Midweek working/Possession working
TSS	£11,583 / £14,981	£16,157 / £20,898	£27,740 / £35,879
OSS	£13,959 / £18,054	£21,584 / £27,917	£35,543 / £45,970
Average ½ Location Case	£30,960 / £39,694	£22,573 / £29,197	£53,263 / £68,891
Total cost per signal – Traditional installation **(1 TSS, 1 OSS, 2 ½ LOC)**	£86,922 / £114,423	£82,889 / £107,209	£169,811 / £221,632
Total cost per signal – ATP level protection installation **(1 TSS, 15 OSS, 16 ½ LOC)**	£712,008 / £920,895	£701,100 / £906,805	£1,413,108 / £1,827,700

Source: Franklin & Andrews 2015

The data in Table C.1 is given on the assumption that each signal requires 1 TSS, 1 OSS and 1 ½ Location Case per signal for Traditional TPWS installation, and 1 TSS, 15 OSS, 16 ½ Location cases for ATP level protection installation . Estimate includes installation costs. Estimates are likely to inflate by up to 60% for possession working.

Mott MacDonald

Appendix C. ORR Guidance

ORR	Railway Guidance Document	RGD-2010-11

Exemptions process under Railway Safety Regulations 1999 (RSR)

Date of issue/ last review	Issued: 28 October 2010 Reviewed December 2013	**Date of next review**	1 April 2015
RGD postholder/owner		Alan Bell, Head of Rail Safety Policy	
RGD cleared by		John Gillespie, Head of Rail Safety Policy and Central Regulation Division	
RGD type		Policy ☐ Information ☐ Procedure ☒	
Target audience	RSD ☒ RPP ☒	Policy ☒ Inspectors ☒ Admin ☒	

Keywords	Exemptions; Handling; Railway Safety Regulations 1999
Summary	This guidance document explains the process involved in handling applications for exemptions under regulation 6 of the Railway Safety Regulations 1999. The regulations contain prohibitions on: • operation of trains without a train protection system; • the operation of Mark I rolling stock; and • the use of hinged doors on passenger trains.
Original consultation	Alan Bell, Tom Wake, Caroline Wake, David Keay and Chris Simms
Subsequent consultation (reviews only)	Alan Bell, John Gillespie, David Keay, Paul Appleton, Tracy Phillips and Laura Majithia

Detail **The legal requirement**

The Railway Safety Regulations ('RSR 1999') include provision for exemptions. The Regulations say:

> *"Exemption certificates6. (1) The relevant authority may, by certificate in writing, exempt any person or class of persons, railway, part of a railway or class of railways, train or rolling stock, or class of train or rolling stock from any prohibition imposed by these Regulations and any such exemption may be granted subject to conditions and to a limit of time and may be revoked by a certificate in writing at any time.*
>
> *(2) Before granting an exemption the relevant authority shall consult such persons as it considers appropriate.*
>
> *(3) In deciding whether to grant any such exemption the relevant authority shall have regard to–*
>
> *(a)the conditions, if any which it proposes to attach to the exemption; .*
>
> *(b)any other requirements imposed by or under any enactment which apply to the case; .*
>
> *(c)all other circumstances of the case."*

Information required from the applicant

The information from the applicant needs to be sufficiently detailed so that ORR can fulfil its responsibilities as it considers, and possibly grants, an exemption certificate under the legal requirement.

Specifically, the applicant (usually the train operator or infrastructure manager) should provide the following information in support of their application:

- A letter to ORR requesting the exemption and summarising the reasons why they think it is required;
- The proposed start date of the operations requiring the exemption;
- The proposed duration of the exemption sought; and
- A risk assessment covering the principal additional risks which could foreseeably arise if the exemption was granted, and the control measures they propose, including (but not limited to):
  - The responsibilities of the different parties involved.
  - The competency requirements for different persons.
  - The means of communications

as much info as possible

For TPWS exemptions:

- An Operational Safety Plan setting out the health and safety measures to be implemented;
- The location of the operations (e.g. the relevant section of the railway); and
- The scope of the operations, (a description of the operations)

For Mark 1 Rolling stock exemptions:

- Name of operator of vehicle(s);
- List of vehicle identification details; and
- Details of modifications made/to be made to improve crashworthiness and prevent vehicle(s) overriding.

For hinged door rolling stock exemptions:

- Name of operator of vehicle(s);
- List of vehicle identification details;
- Details of modifications made/to be made to vehicle(s) for secondary door locking; and
- Operational arrangements for the safe carriage of passengers in hinged door rolling stock.

Submitting the application to ORR

The applications should be sent to the Rail Safety Policy Team. A case officer will be assigned to the application and will forward the application to a case team of relevant safety inspectors (and any other relevant advisers from the Rail Vehicles, Command Control & Signaling or Legal Services teams) ("the case team"). It may not be necessary to involve Legal Services where the application for an exemption involves similar work to an application that has been previously considered.

Considering the application and consultation

- Initially the case team considers whether the applicant has provided enough information. Where necessary the case officer, on recommendation from the case team, may ask the applicant to provide more information in a form that will enable us to reach a decision on the application.
- The case team advises the case officer whether to include the person with delegated authority to sign exemptions under RSR 1999 ("authorising officer") at this stage, or after consultation of relevant stakeholders.
- Where the case team considers that the applicant has provided enough information, then the case officer will carry out a consultation,

	• The original certificate is sent to the applicant/exemption holder and copied to interested parties and ORR retains copies which are placed on its website. • If a decision is made not to grant the exemption (either at this stage or earlier), reasons should be provided to the applicant. **What happens after the certificate has been issued?** • All the original documents are filed (either electronically or in hard copy) for future reference and are published on ORR's website.
Action (optional)	

Appendix D. Current ATP and TPWS fitment assessment

An assessment was carried out on the following plans obtained from the Network Rail EB system to ascertain the number of ATP and TWPS fitted signals, buffer stops, PSRs and Routes.

Table D.1: Current ATP & TPWS Fitment Assessment

Plan Number and Version		ATP Fitted	TPWS Fitted	TPWS Not fitted
S2741 2-2	DV2			
S3610/2/1	JP2			
S3610/2/2	JP2	Distant signals – 1 Stop Signals – 22 UNUSUAL – 3	PSR – 1 Signal (OSS+) – 2 Signal (OSS+ & OSS1) – 2 Signal (TSS Only) – 4 Signal (OSS) – 2	Signal – 21 Distant – 1 PSR – 9 Junction signals reduced speed turnout – 3
S3610/2/3	JP2			
S3610/2/4	JP2			
S3610/2/5	JP2			
S3610/2/6	JP2			
S3610/2/7	JP2			
S3610/2/8	GA1			
S3610/2/9	JX3			
S3610/27/8 SHT 2	GA1			

Appendix E. ATP Loop Installation Information

Table E.1: ATP Loops – Chiltern Lines

Sig Plan Drawing number	Drg ver	Stop sig	Dist sign	Buffer Stops	GPL sig	LOS	Speed	L.C. DCI	LUL Stop sig	LUL Dist sig
S3610/2/1	JP2	16	0	6	5	1	5			
S3610/2/2	JP2	23	1	0	1	1	2			
S3610/2/3	JP2	16	1	0	0	0	0			
S3610/2/4	JP2	30	1	0	1	0	1			
S3610/2/5	JP2	25	0	1	0	1	2			
S3610/2/6	JP2	16	6	1	1	1	3			
S3610/2/7	JP2	10	8	0	0	0	2			
S3610/2/8	GA1	12	4	1	8	1	8	2	0	0
S3610/27/8/2 #A	GA1	4	4	0	0	0	0	0	2	1
S3610/2/9	JX3	12	8	0	0	0	3			
S2741/2/2	DV2	8	5	0	0	0	1			
Totals		172	38	9	16	5	27	2	2	1
272										

Marylebone S.C. Signalling Plans unless stated.

#A = Loc Area Plan - for lines not shown on Signalling Plan S3610/2/8

#B = Banbury South S.B. plan.

The table above details the number and types of ATP fitment as depicted on the signalling records available on the Network Rail ‘eB’ system.

Table E.2: ATP Loops, but no TPWS. – Chiltern Lines

Sig Plan Drawing number	Drg Ver	Stop sig	Dist sign	Buffer Stops	GPL sig	LOS	Speed	L.C. DCI	LUL Stop sig	LUL Dist sig
S3610/2/1	JP2	8	0	0	5	1	3			
S3610/2/2	JP2	14	1	0	1	0	9			
S3610/2/3	JP2	10	1	0	0	0	2			
S3610/2/4	JP2	16	1	0	1	0	4			
S3610/2/5	JP2	17	0	0	0	2	4			
S3610/2/6	JP2	4	6	0	1	0	6			
S3610/2/7	JP2	9	8	0	0	0	0			
S3610/2/8	GA1	0	4	0	8	1	6	2		
S3610/27/8/2 #A	GA1	4	4	0	0	0	0	0	2	1
S3610/2/9	JX3	5	8	0	0	0	5			
S2741/2/2 #B	DV2	4	5	0	0	0	4			
Totals		91	38	0	16	4	43	2	2	1
154										

Marylebone S.C. Signalling Plans unless stated.

#A = Loc Area Plan - for lines not shown on Signalling Plan S3610/2/8

#B = Banbury South S.B. plan.

In the above table the numbers represent signals and speed where there is presently ATP supervision but at which TPWS is not fitted.

The replacement of ATP functionality with a system of TPWS could take one of two routes.

Either the TPWS will be utilised to try and replicate the full functions of the ATP system or an enhanced TPWS fitment is undertaken. TPWS would be fitted to all plain line signals not presently fitted.

As an example of the fitments required for a plain line, single approach, level gradient and standard o/l stop signal if full ATP controlled braking, bringing the strain to a stand before/at the signal, was required to be provided then depending upon the percentage of braking there could be up to 15 sets of OSS loops and a set of TSS loops required at each signal.

If the requirement was to fit TPWS to all signals but to have this function in the same way as conventional TPWS then this would require the fitment of OSS and TSS loops only, at all unfitted main signals. Across all plans this would be 91 main signals. There would however still be the issue of 38 distant signals, 16 GPL's and 5 LOS's. It would be practical to fit TSS and possibly OSS loops at the GPL's and LOS's, though not at the distant signals.

There would still remain the lack of speed control which is provided by the existing ATP system, the system provides control over both permanent and temporary increases and decreases in main line speed as well as control for turnout speed. .

Appendix F. National Class B resignalling schemes letter

Department for Transport

[redacted]
Rail Technical, International and Safety
Department for Transport
Great Minster House
33 Horseferry Road
London
SW1P 4DR
[redacted]
Web Site: www.dft.gov.uk

6 February 2014

[redacted]
Network Rail
90 York Way
London
N1 9AG

Dear [redacted]

National Class B resignalling schemes: Decision of the Competent Authority under regulation 13 of the Railways (Interoperability) Regulations 2011

Thank you for your letter of 18th November requesting a Regulation 13 decision for the national Class B resignalling projects.

On behalf of the Secretary of State I can confirm that the Competent Authority's decision is that authorisation is not required for the upgrade and renewal work for the projects listed in Annex 1 of your letter. This decision is made on the basis of the supplementary information Network Rail have provided as confirmation that each of the class B projects fits with the current UK national ERTMS deployment plan and that eventually ETCS is planned to replace this class B signalling. I note that under Section 7 of the CCS TSI it is not mandatory to fit ETCS on the infrastructure unless the train protection on the high speed route is being upgraded or the route lies on the European Deployment Plan.

I also note that these projects will involve replacing an existing class B system with another class B system and that it is your intention that where feasible the project will deploy components that are capable of upgrade to an ETCS system and in compliance with the TSI. I also note your intention that the functionality of the class B system shall comply with existing national notified rules and remain unchanged. Network Rail's intention is that any current Class B systems remaining in use should not be adversely affected by the work undertaken as part of the projects listed in Annex 1.

This letter ceases to apply if there is a material change to the current CCS TSI provisions concerning the use of class B systems if such a change occurs before NR bring the system into use. Similarly, this letter also ceases to apply to a project in the event that a change in the deployment plan impacts upon that project before the system is brought into use. For example, if ETCS fitment becomes the preferred option instead of the upgrade and renewal of the class B system, or the expected deployment of ETCS is brought forward. In such an event NR may wish to consider the applicability of seeking a further regulation 13 decision for the renewal or upgrade work.

I am copying this letter to [redacted] at the ORR.

Yours sincerely

[redacted]