Report for Network Rail

Option selection report for the Chiltern Train Protection Strategy

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TABLE OF CONTENTS

1 INTRODUCTION 3

2 OPTION SELECTION WORKSHOP 5

2.1 Participants 5

2.2 Workshop Process 5

2.3 Agreed options for assessment 6

2.4 Agreed evaluation criteria 6

3 RESULTS OF THE OPTION SELECTION 8

3.1 Assessment of each option 8

3.2 Conclusion from the assessment of strategic options 27

4 ASSESSMENT OF THE IMPLMENTATION PERIOD 29

5 CONCLUSIONS AND RECOMMENDATIONS 31

6 ACRONYMS AND ABBREVIATIONS 33

1 INTRODUCTION

Following the DoT investigation into the Clapham Junction Rail Accident (1988), recommendations were made regarding the fitment of Automatic Train Protection on the mainline GB railway. Two pilot schemes for ATP were identified covering Chiltern and Great Western; these schemes were implemented in the early 1990s.

The two installed systems are compliant with the current legislative requirements for train protection systems as described in the Railways Safety Regulations 1999 (Termed RSR 99).

Included in RSR 99, is the mandated requirement on the mainline network to provide a track side and train borne train protection system. A 'train protection system' is defined in Regulation 2(1) of RSR 99 as:

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

Following the regulations, there was an acceptance that ATP would be required across the network and, in the interim, TPWS would be provided. Since the 1999 regulations, there have been significant developments in the industry:

- Completion of the installation of TPWS at junction signals (circa. 2003), which, in conjunction with other risk reduction measures, has reduced SPAD risk across the network by 90%.
- The incremental improvement to the deployment of both trackside and trainborne TPWS to improve reliability, availability and effectiveness in stopping trains before they reach a conflict point.
- The development of ETCS, which is planned for installation across the entire main line railway, which will provide an enhanced level of protection compared to TPWS.

Having been installed as part of a trial for nearly thirty years, the ATP system fitted to Chiltern between Marylebone and Aynho Junction is now obsolete; spares are no longer available, and the equipment is not manufactured. Hence, maintaining the existing system is becoming infeasible and alternative train protection strategies need to be considered for the future. System reliability and availability are also declining.

As a consequence of the obsolescence and reliability issues, Network Rail and Chiltern Railways have identified a range of alternative risk control strategies to manage the risk over the area of the rail network over which Chiltern Railways operate.

In order to assess the safety impact of each of the options Sotera Risk Solutions Limited (Sotera) were commissioned to undertake a detailed, independent, risk assessment of the potential future train protection strategies [1]. The results of the assessment were then used as an input to Cost Benefit Analysis and formal option selection, which considered a wider range of decision making criteria. This report presents the output of the option selection to recommend a single option to take forward.

[1] Report for Network Rail - Risk Assessment of the Chiltern Train Protection Strategy, Sotera Risk Solutions Limited, 2020.

2 OPTION SELECTION WORKSHOP

2.1 Participants

The option selection workshop was held on 31st January 2020, at Network Rail's office at Baskerville House, Birmingham, B1 2ND. The participants of the workshop are listed in *Table 1*.

Table 1 Workshop participants

Name	Company	Role
Darren Young	Network Rail	Senior Project Manager
Barry Lawson	Network Rail	Project Manager
Andy Free	Network Rail	Route Asset Manager (Signalling)
Pete Evans	Network Rail	Senior Principles Engineer (Signals)
Dominic Mottram	Network Rail	Area Manager - Chiltern Railways at Network Rail
Mark Bennett	Network Rail	Senior Sponsor
Simon Jarrett	Chiltern Railways	Engineering Assurance Manager
Simon Walker	Chiltern Railways	Head of Fleet Engineering at Chiltern Railways
Peter Dray	Sotera	Facilitator
David Harris	Sotera	Facilitator/Secretary

The assembled team of participants were assessed to have the competency required to make a decision on the optimum future train protection strategy for the Chiltern route.

2.2 Workshop Process

The key stages to the workshop were:

- To agree the set of options available for the future train protection arrangements for Chiltern.
- To agree the evaluation criteria to be applied to each option.
- To apply the evaluation criteria to each option, comparing the strengths and weakness of each option.
- To select an option (or options) to recommend.

- For the selected option(s) determine any optimisation that maximises the delivery of the safety benefits and offsets any potential increase in risk in the interim period while it is implemented.

2.3 Agreed options for assessment

To ensure all possible potential future strategies were considered, a wide set of were identified in advance and reviewed in the workshop. The upgrades involved lineside and trainborne upgrades. The full range of options included:

1. Maintaining the existing ATP for Chiltern.
2. Switching ATP off and relying on existing TPWS provision.
3. Enhanced trackside TPWS from Marylebone to **Aynho Junction** (to latest standards and fitment to plain line signals).
4. Enhanced trackside TPWS from Marylebone to **Birmingham Moor Street** (to latest standards and fitment to plain line signals).
5. Enhanced trackside TPWS from Marylebone to **Aynho Junction** (to latest standards and fitment to plain line signals) together with upgrades to Chiltern train TPWS to Mk4 units.
6. Enhanced trackside TPWS from Marylebone to **Birmingham Moor Street** (to latest standards and fitment to plain line signals) together with upgrades to Chiltern train TPWS to Mk4 units.
7. ETCS L2 Limited supervision for Chiltern Marylebone to Aynho Junction.
8. Enhanced trackside TPWS Marylebone to Aynho Junction together with ETCS L2 Limited supervision for Chiltern (Marylebone to Aynho Junction).
9. ETCS full supervision for Chiltern (Marylebone to Aynho Junction).

Note: for all the above options, the risk assessment is based upon the assumption that ATP is switched off by 2021 (other than for Option 1). This assumption enables the assessment to compare the relative safety of maintaining ATP with the alternative strategies. In practice, ATP would be maintained for as long as practical whilst an alternative strategy is implemented, which is the subject of *Section 4*.

The workshop participants agreed that this was a comprehensive set of options although there may be some minor modification or optimisation should they be recommended for implementation.

2.4 Agreed evaluation criteria

The evaluation criteria included:

1) Safety Performance - train accidents
   a) Final (2026+)

b) Interim
c) Further mitigations

2) Safety Performance – other
3) Operational impact
   a) Normal
   b) Degraded/emergency
4) Cost
   a) Capital
   b) Ongoing
5) Deliverability/uncertainty
   a) Technical feasibility
   b) Delivery within timescales
   c) Maintainability
6) Impact on other parties (eg, TOCs)
7) Alignment with business objectives
8) Regulatory position.

3 RESULTS OF THE OPTION SELECTION

3.1 Assessment of each option

The conclusions from the evaluation of each option are presented in this section. For each option, a chart is provided which indicates the train accident risk:

1) The level of risk at four points in time, including:

    a) The end of 2019 (the base case for assessment accounting for existing ATP and service levels).

    b) The end of 2021, accounting for additional HS2 construction traffic and increased passenger demand.

    c) The end of 2024, accounting for East-West rail traffic and further passenger demand.

    d) The end of 2026, which is the end point for the assessment.

2) Each bar is separated into two components, the lower darker bar indicated the risk in the Marylebone to Aynho junction section of railway (i.e. the section of the route within which ATP currently operates), the lighter bar is for the rest of the railway over which Chiltern Railways operates. The bars cover all operators that run trains over the same route sections as Chiltern Railways, including freight operators.

3) There are three reference lines, the higher (red) one indicating the risk that would result if Chiltern ATP was permanently switched off in 2021 and no additional mitigations were introduced. A solid green line indicating the level of risk that would result if ATP could be maintained without any reduction in availability or reliability in the longer term. A dotted green line indicating the risk on the ATP protected area between Marylebone and Aynho junction (i.e. the area where ATP is currently fitted) if ATP could be maintained without any reduction in availability or reliability in the longer term.

For all options (other than Option 1) there is a risk increase in 2021 due to the assumption that ATP is switched off by 2021 which is before additional safety controls could be implemented. The management of risk in the transitional period (without ATP switched-off) is the subject of *Section 4*.

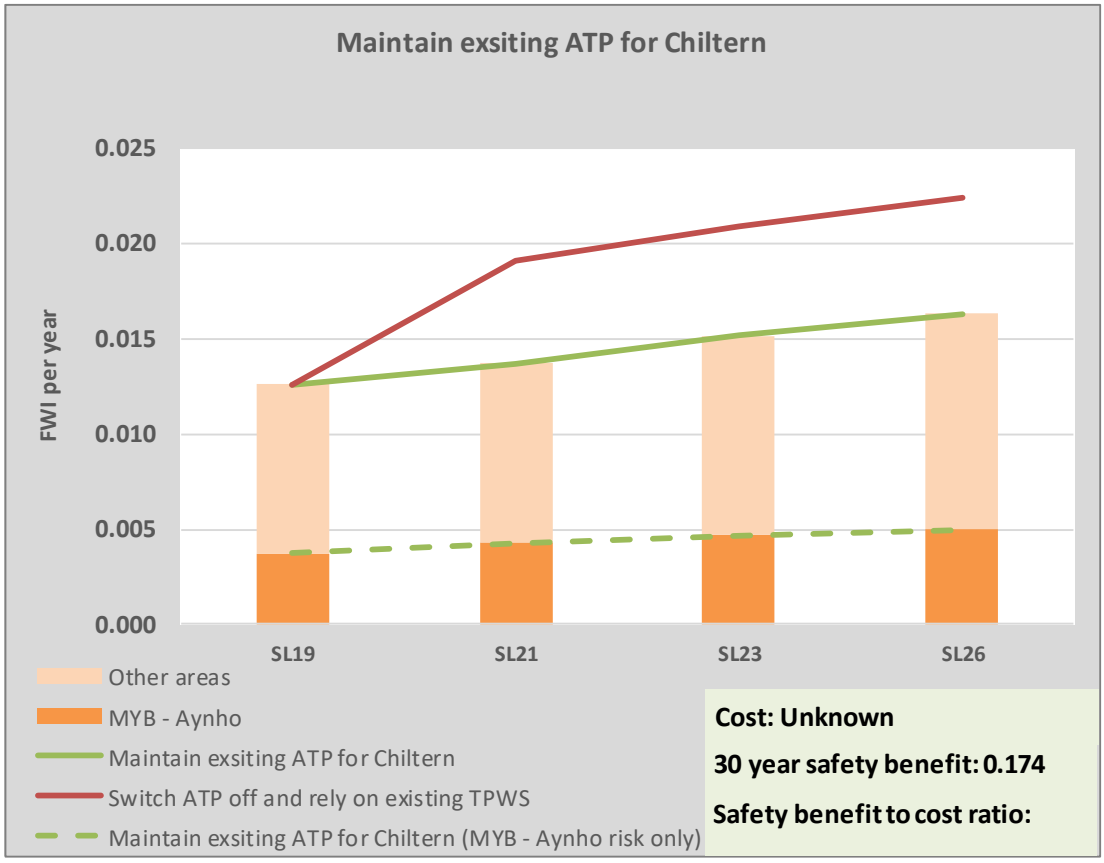
The risk assessment results presented are derived from a detailed train accident risk model developed for the railway over which Chiltern Railways operates. The risk model assesses the train-train collision, buffer collision and derailment risk (from overspeeding). The model accounts, in detail, for the trackside and trainborne train protection arrangements, the train services operated and the layout of the railway.

Details of the approach to the risk assessment and the results can be found in a previous report[1].

Option 1: Maintain the existing ATP for Chiltern

Safety Performance: This option, in principle, would maintain the existing level of train accident risk. In the future cases there will be modest increases in the baseline level of risk through higher network utilisation (passenger journeys) and the introduction of additional services, such as East-West Rail (see *Figure 1*).

Figure 1 Train accident risk for Option 1



In practical terms, the ATP system is now obsolete: the technology is not supported, spares are no longer available and stored spares are now at a critical level. Consequently, without an alternative strategy, as the trainborne units continue to fail, risk would increase through either withdrawing trains from service and causing knock-on risk through delays and cancellations, or alternatively, the trains would be operated with the fitted Mk1 TPWS units only. The Mk1 TPWS units provide a significantly lower level of train protection than ATP. At the current time trains with failed ATP equipment are normally operated without the ATP functional until the end of the day. A consequence of the increasing ATP system failure rate and operation with ATP in a failed state may mean that the

[1] Sotera Risk Solutions Ltd, A report for Network Rail - Risk Assessment of the Chiltern Train Protection Strategy, January 2020.

potential increase in risk is accelerated and well above that shown in the chart above where it is assumed that the ATP system on all fitted stock can be maintained in a functional state.

Costs: There are no capital costs associated with operating the existing system, however, the system is not sustainable. A previous report has investigated the possibility of re-engineering the existing ATP system, which was found to be impractical [(1)].

Deliverability and uncertainty: The existing system is not deliverable or maintainable due to the obsolescence reasons presented above. Furthermore, pursuit of the option would result is progressive deterioration of safety levels in order to maintain service levels. Hence this is not a viable option for the future.

Impact on other parties: There is negligible impact on other parties of operating ATP. Where Chiltern Railways operate over LUL infrastructure, the ATP system provides roll-back protection. If the system is replaced, the functionality would need to be provided through alternative technology as roll-back protection is a requirement to operate over LUL infrastructure.

Alignment with business objectives: The existing ATP system is not aligned with the Network Rail commitment for system-wide deployment of ETCS. Should additional stock fail, Chiltern Railways would not be able to provide a service compatible with the timetable, unless they were permitted to operate trains relying on the existing TPWS system.

Regulatory position: The existing ATP is entirely compliant with the Railway Safety Regulation 1999, for train protection. Hence it is the legal baseline.

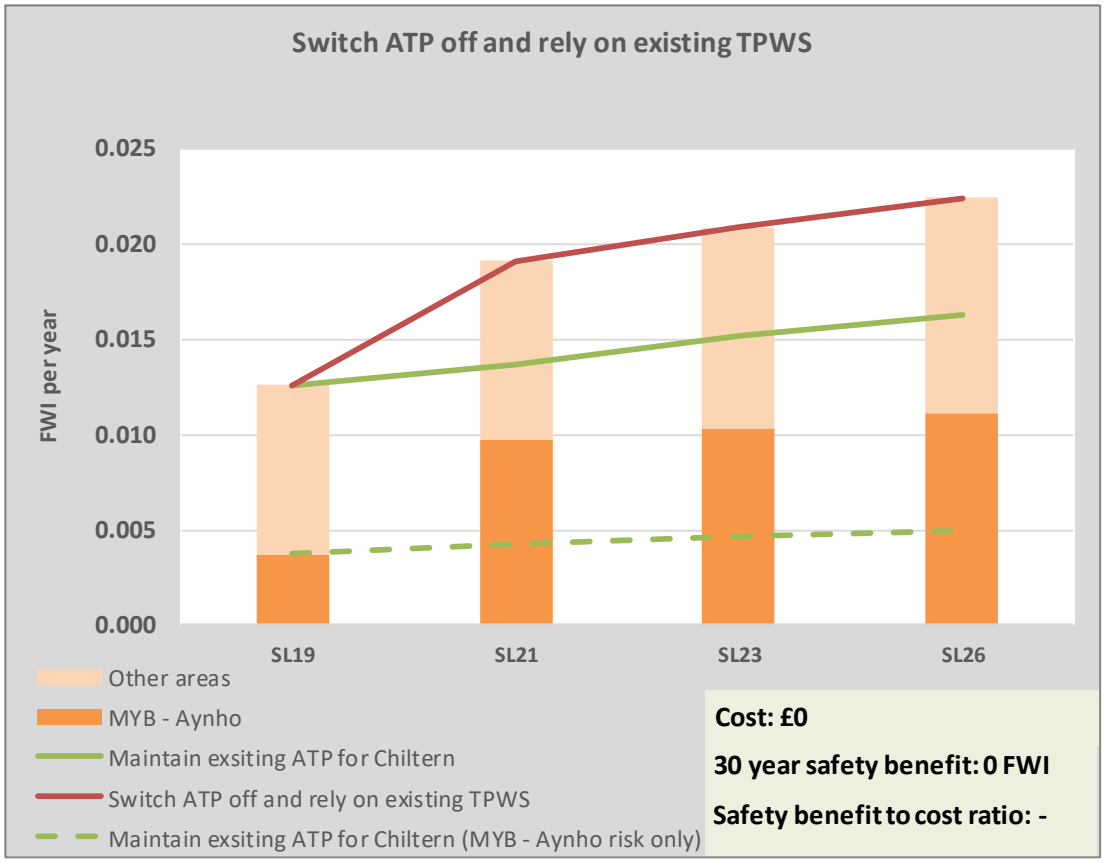
Conclusion: The critical issue of system obsolescence means it is not feasible to maintain the existing ATP system, therefore this is not a practical option to progress as a future strategy.

Option 2: Switch ATP off and rely on existing TPWS provision

Safety: Switching-off ATP would result in a significant train accident risk increase (of approximately 40%) between Marylebone and Aynho Junction. Whilst this would mean that the level of protection is comparable to that on most of the rail network, the option is not considered sustainable. The level of train accident risk from this option is shown in *Figure 2*.

[1] Mott MacDonald, Options for Interim Solution on Chiltern ATP Routes, March 2015, NR 3893399/01.

Figure 2 Train accident risk for Option 2



Switching off ATP would also result in a small risk increase on London Underground infrastructure as ATP also provides rollback protection which is requirement for operation on their infrastructure.

Operational performance: Operating with ATP switched-off would result in a modest operational performance improvement as approximately 10% of fleet failures are connected with ATP system failures. It is estimated that there could be a 1-2% operational performance improvement from switching-off ATP.

Cost: Switching ATP off would result in a moderate saving in terms of trackside and trainborne maintenance and from response to failures.

Deliverability and uncertainty: Of all the options considered this is the most deliverable and least uncertain option. In practical terms, the system is not likely to be switched off, but would be kept running until it could no longer be maintained. It has been estimated that the system is likely to deteriorate at a rate of approximately 20% per year (as a realistic worst case). The impact of this on safety performance is discussed in more detail in *Section 4*.

Impact on other parties: There would be an issue delivering roll back protection, which is a requirement for operating on London Underground infrastructure.

Alignment with business objectives: Consultation with the Network Rail Regional Executive has indicated that the risk increase is intolerable; there are other achievable options that do not result in a risk increase.

The option is also thought likely to be unacceptable to the Chiltern Railways' board.

Regulatory position: As this option would involve switching-off ATP and it would be reasonably practical to maintain some ATP, the early removal would require an exemption against RSR 1999.

Conclusion: Whilst this option would reduce costs and delays, it is not considered viable or sustainable due to the increase in train accident risk.

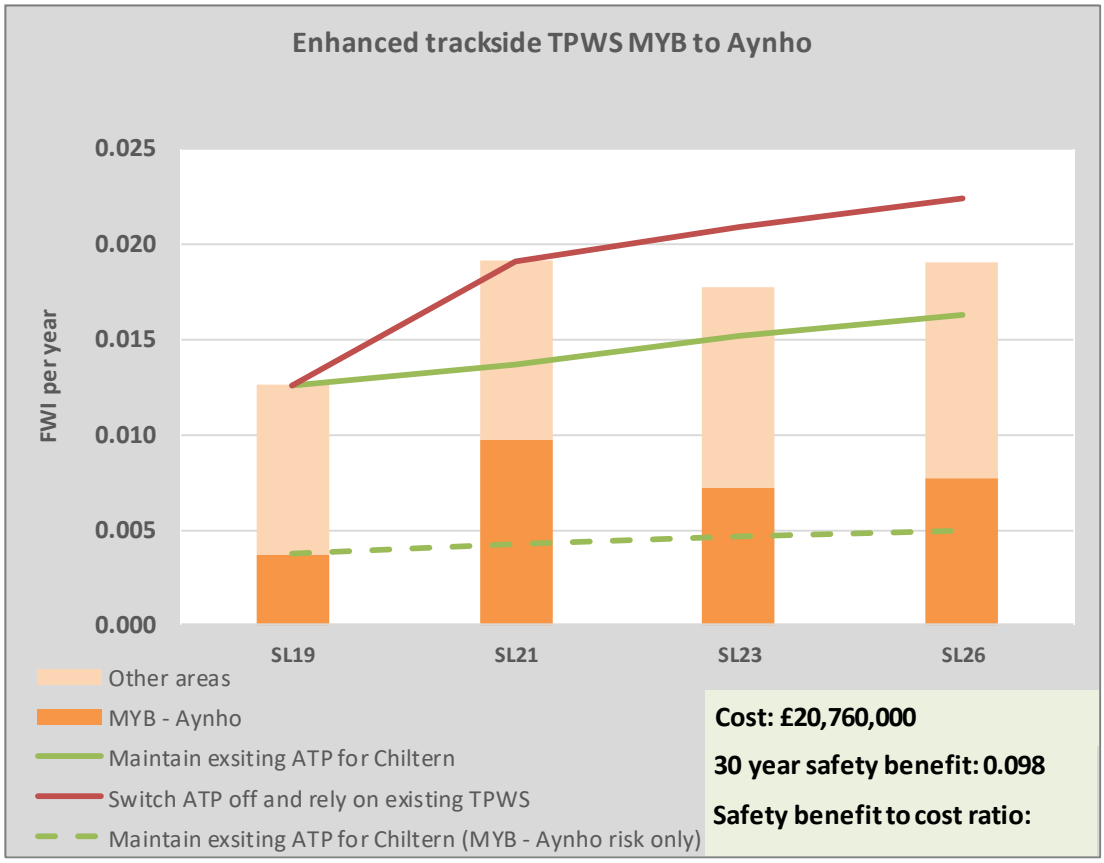
*Option 3: Enhanced trackside TPWS from Marylebone to **Aynho Junction** (to latest standards and fitment to plain line signals)*

Note: The trackside TPWS fitment on much of the UK railway is not to the latest standards; this option includes updating the fitment of junction signals to the latest standards together with provision of TPWS at plain line signals. Hence, the option would provide a degree of enhanced protection at junction and plain line signals although this would be limited at junction signals as many already meet current standards. For this option the upgrade would include trackside fitment between Marylebone and Aynho junction only and switching-off ATP.

Safety: This option provides a level of safety risk that is moderately higher than the current level with ATP fully operational (see Figure 3). Whilst this would mean that the level of protection is similar, and slightly enhanced, compared to most of the rail network, the option is not considered viable due to the risk increase that would result between Marylebone and Aynho Junction.

Alternative technology would also be required to provide rollback protection to enable operation on London Underground infrastructure.

Figure 3 Train accident risk for Option 3



Operational performance: Operating with ATP switched-off would result in a modest operational performance improvement as approximately 10% of fleet failures are connected with ATP system failures. It is estimated that there could be a 1-2% operational performance improvement from switching-off ATP. However, there may be additional delays due to failures and activations resulting from the additional TPWS fitment.

Cost: The capital cost of this option is approximately £20.8m.

Deliverability and uncertainty: Of all the options considered, this option is highly deliverable and one of the least uncertain options. It is estimated that the option could be delivered by the end of 2023.

A benefit of the TPWS options is that trackside maintenance can be undertaken by a larger pool of competent maintainers, ie, ATP is highly specific with a relatively small number of maintainers. Furthermore, spares for lineside TPWS are readily available.

It should be noted that in practical terms, the ATP system would not be switched off, but kept running until it could no longer be maintained.

Impact on other parties: There would be an issue delivering roll back protection, which is a requirement for operating on London Underground infrastructure.

Alignment with business objectives:

Consultation with the Network Rail regional executive has indicated that a risk increase is intolerable; there are other achievable options that do not result in a risk increase.

Regulatory position: As this option would involve switching-off ATP, the train protection system in place would no longer meet the requirements of RSR 1999 and therefore an exemption would be required.

Conclusion: Whilst this option may result in reduced delays, it is not considered viable due to the increase in train accident risk.

*Option 4: Enhanced trackside TPWS from Marylebone to **Birmingham Moor Street** (to latest standards and fitment to plain line signals).*

From a technical perspective, this option is comparable to Option 3 but provides enhanced TPWS on the entire route between Marylebone and Birmingham Moor Street; this includes areas not currently fitted with ATP.

Safety: Overall, this option provides a level of safety risk that is slightly improved compared to the current level with ATP fully operational (see the last bar in *Figure 4*). In the chart, TPWS between Marylebone and Aynho junction is delivered by 2023 and from Aynho Junction to Birmingham Moor Street by 2026. The overall risk reduction compared to ATP is achieved through a balance of two factors:

- a risk decrease in the non-ATP fitted area between Aynho Junction and Birmingham Moor Street, with the risk decrease being spread amongst all TOCs that operate over this route.

- a risk increase in the (currently) ATP fitted area between Marylebone and Aynho Junction with the risk increase being concentrated almost entirely on Chiltern Railways.

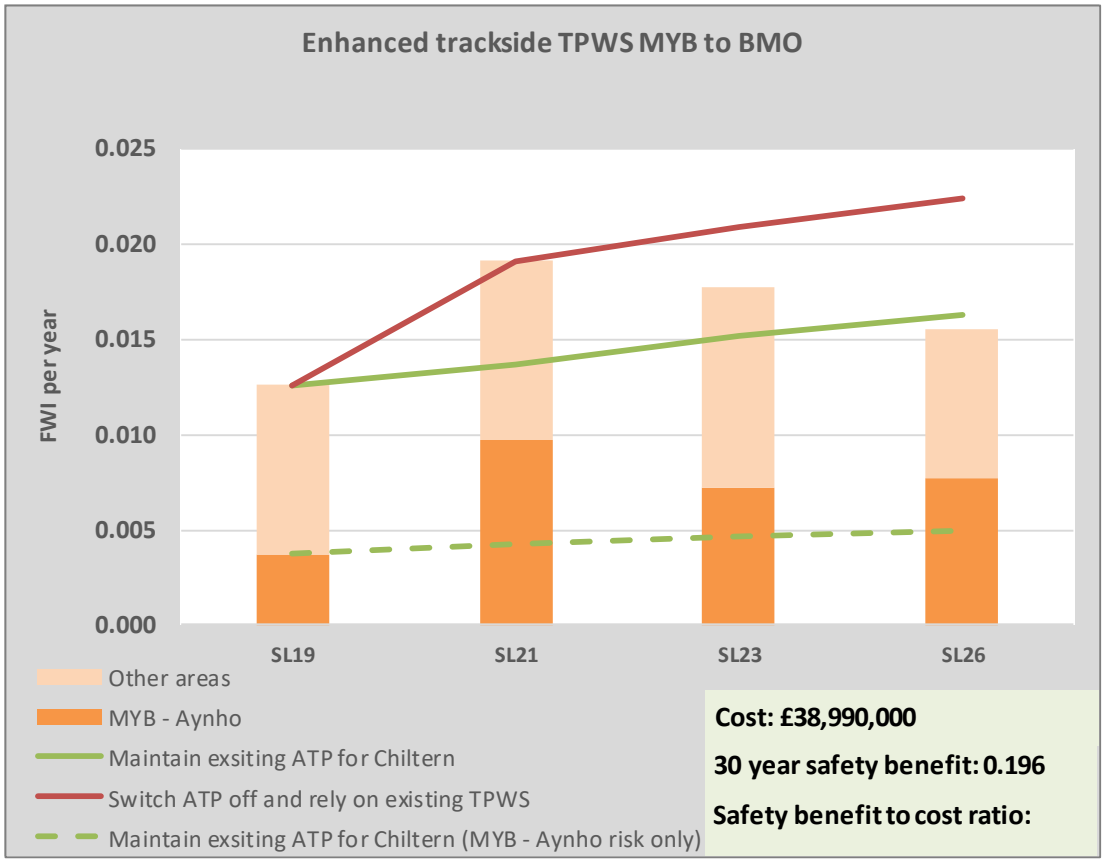
Overall, the first of the two factors, the risk decrease north of Aynho is slightly larger than the increase between Marylebone and Aynho Junction.

This option would mean that the level of protection between Marylebone and Birmingham Moor Street is similar, and slightly enhanced, compared with most of the rail network.

Whilst the option provides an overall risk reduction, it was not considered acceptable to offset a risk increase on one part of the network with a risk increase in another, where an alternative risk mitigation focussing on the ATP fitted area can be shown to be effective.

Alternative technology would also be required to provide rollback protection which is requirement for operation on LUL infrastructure.

Figure 4 Train accident risk for Option 4



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

Cost: The capital cost of this option is approximately £39m, which exceeds the provision in the CP6 settlement.

Deliverability and uncertainty: This option uses existing technology and is therefore highly deliverable and is one of the least uncertain options. Consultation with other non-Chiltern Railways operating companies would be required as additional TPWS will impact their services. It is estimated that this option could be delivered by 2025-2026.

A benefit of the TPWS options is that trackside maintenance can be undertaken by a larger pool of competent maintainers, ie, ATP is highly specific with a relatively small number of maintainers. Furthermore, spares for lineside TPWS are readily available.

Impact on other parties: There would be an issue delivering roll back protection, which is a requirement for operating on London Underground infrastructure.

Safety benefits and potentially performance disbenefits would be accrued by other train operators.

Alignment with business objectives: It was not considered tolerable to accept a risk increase in the Marylebone to Aynho Junction area with the risk increase being offset on another part of the Network. There are other achievable options that do not present this compromise and deliver a similar level of safety between Marylebone and Aynho Junction and have a lower total cost.

The option would be compatible with the industry's migration strategy to eventually transition from a railway protected by TPWS to one protected with ETCS.

Regulatory position: As this option would involve switching-off ATP, the train protection system in place would no longer meet the requirements of RSR 1999 and therefore an exemption would be required. This is because a requirement of the RSR 1999 is to provide a system that ensures the permitted speed is not exceeded throughout the journey, which is not provided by TPWS.

Conclusions: Whilst this option would maintain safety levels overall, it is not considered viable due to the increase in train accident risk between Marylebone and Aynho junction, even though the level of risk increase is offset by a reduction in risk between Aynho Junction and Birmingham Moor Street.

*Option 5: Enhanced trackside TPWS from Marylebone to **Aynho Junction** (to latest standards and fitment to plain line signals) together with upgrades to Chiltern train TPWS to Mk4 unit*

This option is similar to option 3, but also provides Chiltern Railways' cabs with Mk4 TPWS. Mk4 TPWS units provide protection against 'reset and continue' SPADs as well as in-service health monitoring.

Safety: Overall, this option provides a level of safety risk that is slightly improved compared to the current level with ATP fully operational (see the final two bars of *Figure 5* for which it is assumed that the upgrades can be achieved by the end of 2023*)*. This is because all stock operating in the Marylebone to Aynho Junction would benefit from the enhanced lineside TPWS (not all trains operate under ATP in the area). Furthermore, the benefit of the Mk4 TPWS units providing protection against 'reset and continue' SPADs and in-service monitoring would also apply to Chiltern services north and west of Aynho junction.

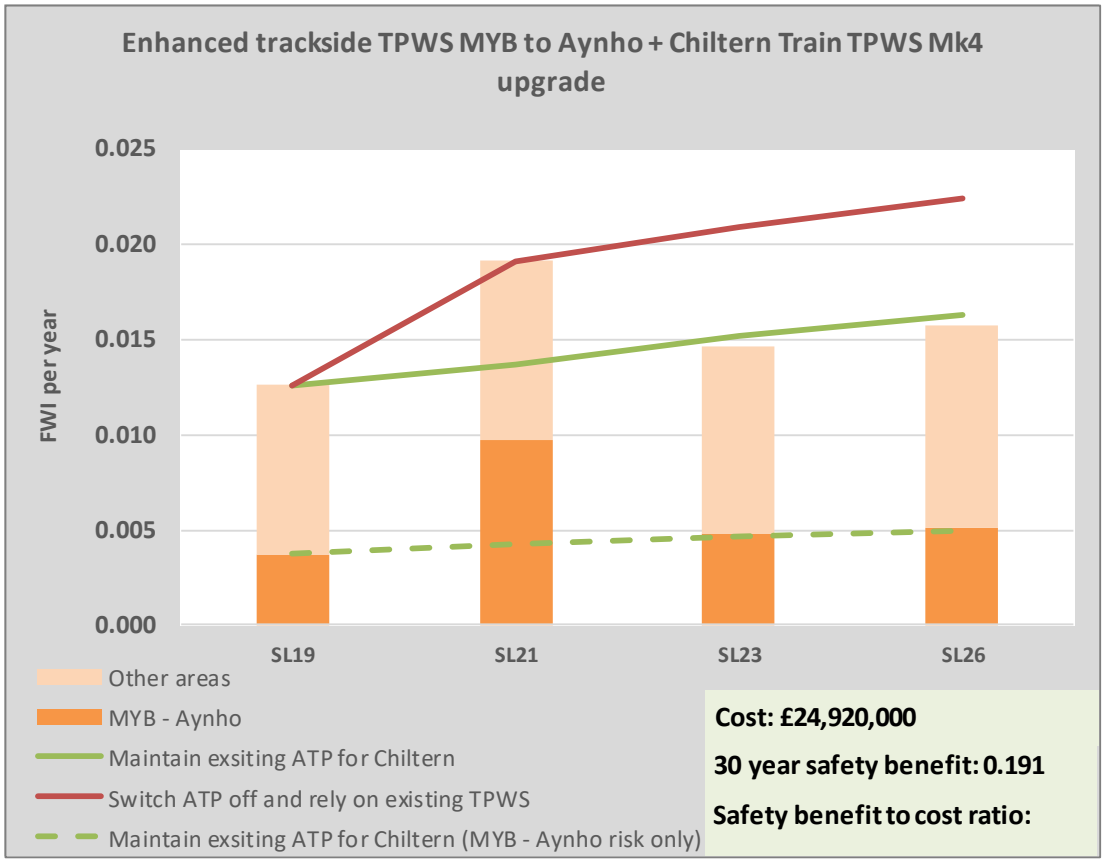
It should be noted that with this (and other) options there will necessarily be a transition period during the implementation which may result in a short-term increase in risk. This would be brought about through:

- The need to take ATP stock out of service to implement the TPWS Mk4 upgrade.
- The potential for trainborne ATP to fail during the transition period.

Strategies to minimise the impact of this are discussed in *Section 4*.

As with all options that involved the termination of ATP, alternative technology would be required to provide rollback protection on London Underground infrastructure; this could be provided alongside the Mk4 TPWS unit fitment.

Figure 5 Train accident risk for Option 5



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

During the implementation period, there is the potential for the fleet capacity to be constrained as units are taken out of service to receive the upgraded TPWS units. This limits the speed at which TPWS upgrades can

be rolled-out. Installation of TPWS Mk4 is complicated due to the need to also upgrade the OTMR.

Cost: The capital cost of this option is approximately £25m including trackside and trainborne upgrades. The cab fitment costs are estimated by Chiltern Railways to be approximately £38.5k per cab, which includes design, integration of a new OTDR, ATP removal and disposal and provision of rollback protection.

Deliverability and uncertainty: This option uses existing technology and is therefore relatively deliverable and is one of the least uncertain options. One area of uncertainty is the time required to upgrade the train cabs to the Mark 4 units, for which there is limited experience within the industry. The upgrade requires significant rewiring as well as new OTDR units. In order to manage the loss of stock while units are being upgraded, a rolling programme of cab upgrades would be adopted, which could be achieved in the period between 2021 and the end of 2023. A similar timeframe would be required for the lineside fitment.

A benefit of the TPWS options is that trackside maintenance can be undertaken by a larger pool of competent maintainers, ie, ATP is highly specific with a relatively small number of maintainers. Furthermore, spares for lineside TPWS are readily available.

Impact on other parties: There would be an issue delivering roll back protection, which is a requirement for operating on London Underground infrastructure.

Alignment with business objectives: The option would be compatible with the industry's migration strategy to eventually transition from a railway protection by TPWS to one protected with ETCS. Therefore, this option has good alignment with business objectives.

Regulatory position: As this option would involve switching-off ATP, the train protection system in place would no longer meet the requirements of RSR 1999 and therefore an exemption would be required. As with all options relying on TPWS, a requirement of the RSR 1999 is to provide a system that ensures the permitted speed is not exceeded throughout the journey.

Conclusion: This option achieves an improved level of safety performance, has low uncertainty and can be achieved relatively expediently. The costs of this options are disproportionate to the safety benefit, with a benefit to cost ratio of 0.012. However, of the options considered, the ratio is relatively high and within the funding envelope provided by the ORR for the CP6 period. Hence, it is considered to be a viable option.

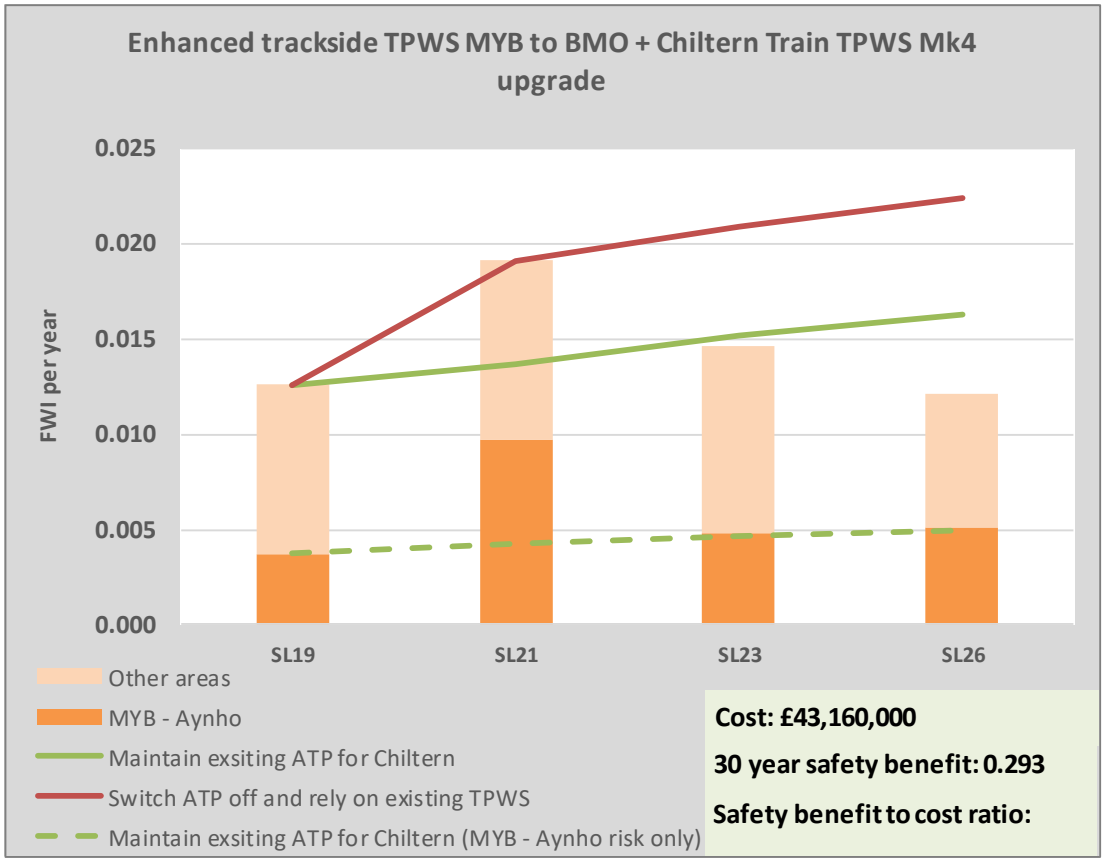
*Option 6: Enhanced trackside TPWS from Marylebone to **Birmingham Moor Street** (to latest standards and fitment to plain line signals) together with upgrades to Chiltern train TPWS to Mk4 units*

Safety: Overall, this option provides a significantly improved level of train accident safety risk by 2026 (See *Figure 6*). This is because all operators over the line between Marylebone and Birmingham Moor Street would benefit from the enhanced lineside TPWS. Furthermore, the Mk4 TPWS units for Chiltern would provide protection against 'reset and continue' SPADs and in-service monitoring; this benefit also applying to services north and west of Aynho junction.

It is assumed that trainborne TPWS upgrades can be completed by the end of 2023, lineside TPWS upgrades can be achieved by 2023 south of Aynho and to Birmingham Moor Street by 2026.

As with all options that involved the termination of ATP, alternative technology would also be required to provide rollback protection for operation on London Underground infrastructure; this could be provided alongside the Mk4 TPWS unit fitment.

Figure 6 Train accident risk for Option 6



Operational performance: Operating with ATP switched-off would result in a modest operational performance improvement between Marylebone and Aynho Junction due to eliminating ATP failures. However, there may be additional delays due to failures and activations resulting from the additional TPWS fitment between Marylebone and Birmingham Moor Street.

As with Option 5, during the implementation period, there is the potential for the fleet capacity to be constrained as units are taken out of service to receive the upgraded TPWS units. This limits the speed at which TPWS upgrades can be rolled-out. The installation of TPWS Mk4 is complicated due to the need to also upgrade the OTMR.

Cost: The capital cost of this option is approximately £43.1m including trackside and trainborne upgrades, which exceeds the budget in the CP6 settlement.

Deliverability and uncertainty: This option uses existing technology and is therefore deliverable and is one of the least uncertain options, although consultation would be required with other TOCs; those that operate north and west of Aynho junction. A rolling programme of track side and lineside upgrades would be required, which could be achieved in the period between 2021 and the end of 2026.

A benefit of all TPWS options is that trackside maintenance can be undertaken by a larger pool of competent maintainers, ie, ATP is highly specific with a relatively small number of maintainers. Furthermore, spares for lineside TPWS are readily available.

Impact on other parties: Engagement would be required with other operating companies that run over the same infrastructure as they may receive additional TPWS activations (alongside safety benefits) from the enhanced level of fitment.

There would be an issue delivering roll back protection, which is a requirement for operating on London Underground infrastructure.

Alignment with business objectives: This option has good alignment with business objectives. The end state presents a lower risk than the current operation with ATP.

The option would be compatible with the industry's migration strategy to eventually transition from a railway protection by TPWS to one protected with ETCS.

Regulatory position: As this option would involve switching-off ATP, the train protection system in place would no longer meet the requirements of RSR 1999 and therefore an exemption would be required. As with all options relying on TPWS, a requirement of the RSR 1999 is to provide a system that ensures the permitted speed is not exceeded throughout the journey.

Conclusion: Whilst this option delivers significantly improved safety, the additional cost of this option compared to Option 5 is approximately £18.2m. The additional cost is vastly disproportionate to the safety benefit of 0.0036 FWI per year. Hence, this option is not considered practicable and not taken forward.

Option 7: ETCS L2 Limited supervision for Chiltern Marylebone to Aynho Junction

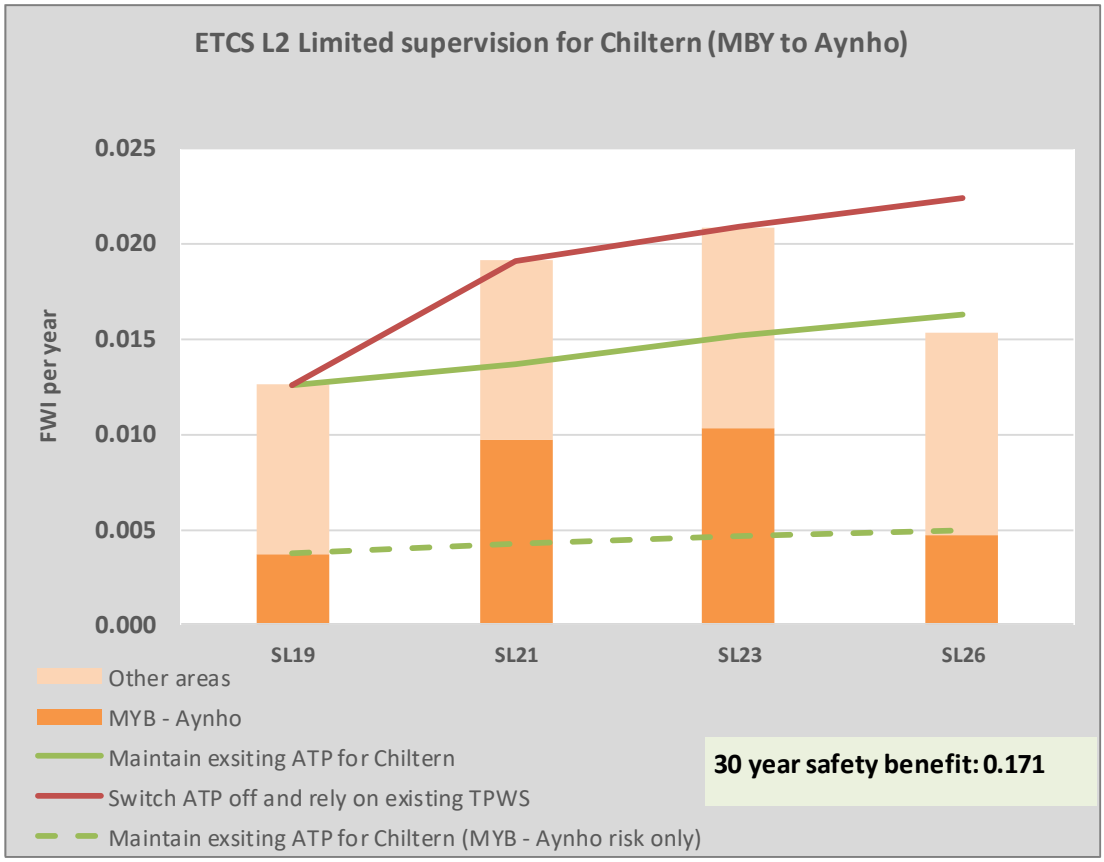
This option includes the use of a new technology involving a 'TPWS Mk5' unit. The units would:

- When operating as a TPWS unit, provide the same functionality as a Mk4 TPWS unit with protection against TPWS 'reset and continue' events as well as in-service monitoring to detect faults.
- When enabled with suitable lineside equipment, have the functionality to ascertain the status of signals ahead and ensure the train's speed profile is consistent with stopping at red signals.

The enhanced functionality, termed *ETCS L2 Limited supervision* could be provided between Marylebone to Aynho Junction. Note: The system may not operate under standard ETCS or in ETCS Limited Supervision mode.

Safety: In the longer term, this option provides a significantly improved level of train accident safety risk. This is because all Chiltern Railways' services between Marylebone to Aynho Junction would receive a level of protection similar to ATP. Outside of the core area, the trains would receive the additional benefits of TPWS units equivalent to the Mk 4 design. For the purposes of the assessment, it is assumed that the in-cab units and track side upgrades could be delivered by the end of 2026

Figure 7 Train accident risk for Option 7



The main safety concern with this option is that it is not yet commercially available and has not gone through approval. Therefore, it is uncertain when (and whether) it could be implemented. In the period prior to its implementation, there would be the potential for significantly increasing numbers of ATP trains to have failed ATP units, such that there would be a significant short to medium term increase in risk.

Operational performance: The reliability of the system is unknown; it is likely to result in additional interventions in the Marylebone to Aynho Junction area in the short term as drivers become familiar with the system as it will provide continuous speed monitoring.

Cost: The capital cost of the lineside upgrade for this option is unknown as it is expected to require significant enhancement to the GSMR infrastructure to support radio data coverage.

The cab costs are also unknown but can be expected to be much higher than TPWS due to the more complicated interfaces to traction and braking systems.

Deliverability and uncertainty: Of all the options considered, this option carries the highest level of uncertainty in terms of deliverability. The costs are unknown and the product has not been fully developed or approved and it is not known when it will be commercially available. There is also the possibility that the system does not make it to market. Hence, it is not possible to start planning implementation until the system is fully developed. It is assumed that it may be available in 2023 but this is highly uncertain.

Given the high level of uncertainty, this option is not considered to be compatible with providing a deliverable strategy to responding to ATP unreliability and potentially increasing safety risk.

Impact on other parties: Prior to implementation, a wider strategy would be required as other operators may decide to implement the system due to the enhanced level of train protection provided.

Alignment with business objectives: The option would be compatible with the industry's migration strategy to eventually transition to ETCS as both require GSM-R data. Hence, the option has good alignment with business objectives and could be a good long-term option nationally.

Regulatory position: This option is likely to meet the requirements of RSR 1999, although this is to be confirmed. The interim period would be without a fully functioning ATP system and therefore a limited exemption would be required.

Conclusion: Whilst this option could deliver long term safety benefits, the uncertainty with the timescales of product availability and the possibility of not achieving approval mean that it is not a viable option to address the short-term issue of ATP obsolescence. Hence, this option is not recommended for progression as part of the current Chiltern train protection strategy.

Once the system is more developed, it may become a viable future option and therefore its development should be monitored during the exemption period.

Option 8: Enhanced trackside TPWS Marylebone to Aynho Junction together with ETCS L2 Limited supervision for Chiltern (Marylebone to Aynho Junction)

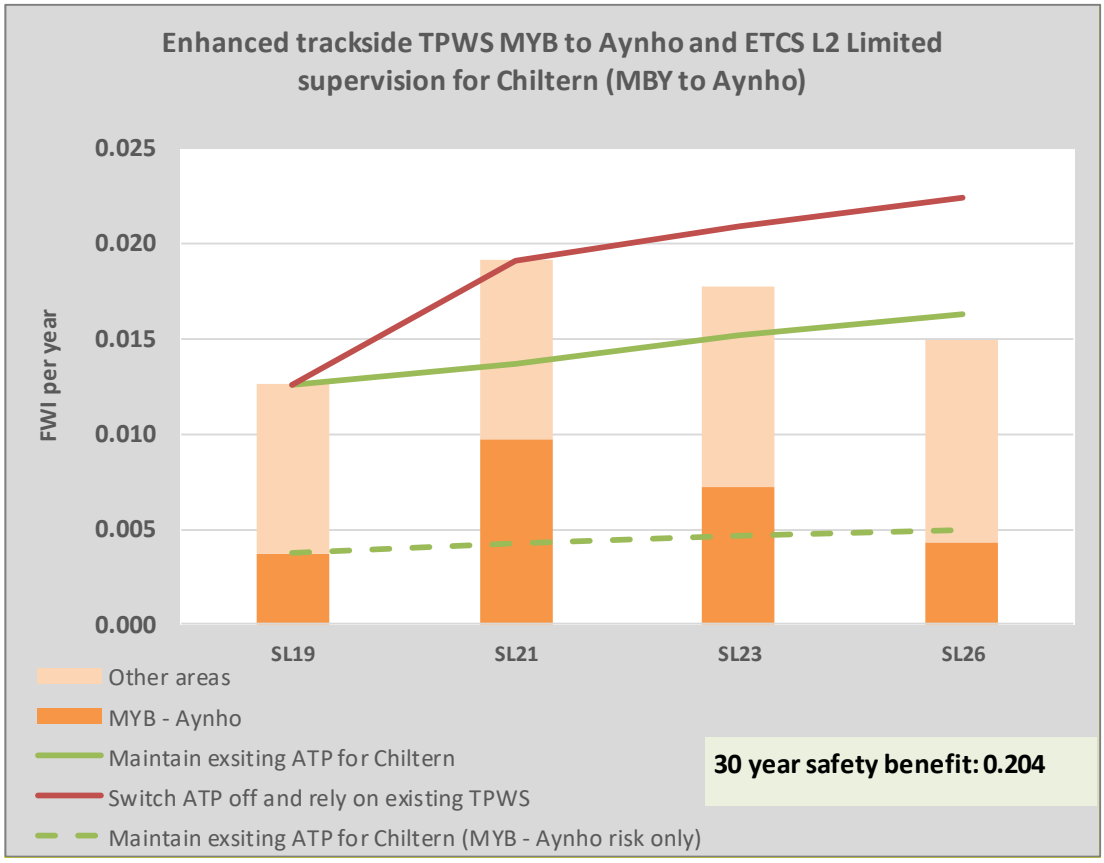
This option is analogous to Option 7, with the addition of providing lineside TPWS enhancements between Marylebone and Aynho Junction.

Safety: Similar to Option 7, this option provides a high level of train protection in the long term. Some of the short-term risk increase from

Marylebone to Aynho junction that would result from the loss of ATP is offset by the enhanced lineside TPWS (see *Figure 8*). However, the in-cab derived safety benefits of the Mk 5 unit would be deferred for at least an additional three years compared to the provision of the Mk 4 unit which is commercially available.

The safety benefit of the additional lineside TPWS would be for a short duration only as TPWS would not be the primary means of train protection once ETCS L2 Limited supervision is implemented; as most of the services south of Aynho Junction are operated by Chiltern the benefit for other operators would be limited. It is assumed that the enhanced lineside TPWS could be implemented by 2023 and ETCS L2 Limited Supervision could potentially be implemented by 2026, although this is highly uncertain. Hence the full safety benefits from the enhanced lineside TPWS would only accrue for about 3 years.

Figure 8 Train accident risk for Option 8



Operational performance: The reliability of the ETCS L2 Limited Supervision system is unknown, however, it is likely to result in additional interventions in the Marylebone to Aynho Junction area in the short term as driver become familiar with the continuous speed monitoring. However, this may be offset by switching off ATP, which currently contributes to the frequency of service affecting failures.

Cost: The capital cost of the lineside GSM-R upgrade for this option is unknown as it is expected to require significant enhancement to the GSM-R infrastructure to support radio data coverage.

The cab costs are also unknown but can be expected to be much higher than TPWS due to the more complicated interfaces to traction and braking systems.

The enhanced TPWS would cost approximately £20.3m.

Deliverability and uncertainty: The cost and deliverability of the ETCS L2 Limited Supervision system are unknown, the product has not been developed or approved and it is not known when it will be commercially available. There is also the possibility that the system does not make it to market. Hence it carries a very high level of uncertainty in terms of deliverability. It would not be possible to start planning implementation until the system is fully developed.

Given the high level of uncertainty of when the safety benefits of the TPWS Mk 5 units could be delivered, it is not considered to be compatible with providing a deliverable strategy for responding to ATP unreliability and potentially increasing safety risk.

The enhanced lineside TPWS element of the option would be deliverable by the end of 2023.

Impact on other parties: As with Option 7, prior to implementation, a wider strategy would be required as other operators may decide to implement the system due to the enhance level of train protection provided.

Alignment with business objectives: As with Option 7, this strategy would be compatible with the industry's migration strategy to eventually transition to ETCS as both require GSM-R data. Hence, the option has good alignment with business objectives and could be a good long-term option nationally.

Regulatory position: This option may meet the requirements of RSR 1999, however, the interim period would be without a fully functioning ATP system and therefore an exemption to cover the interim period would be required.

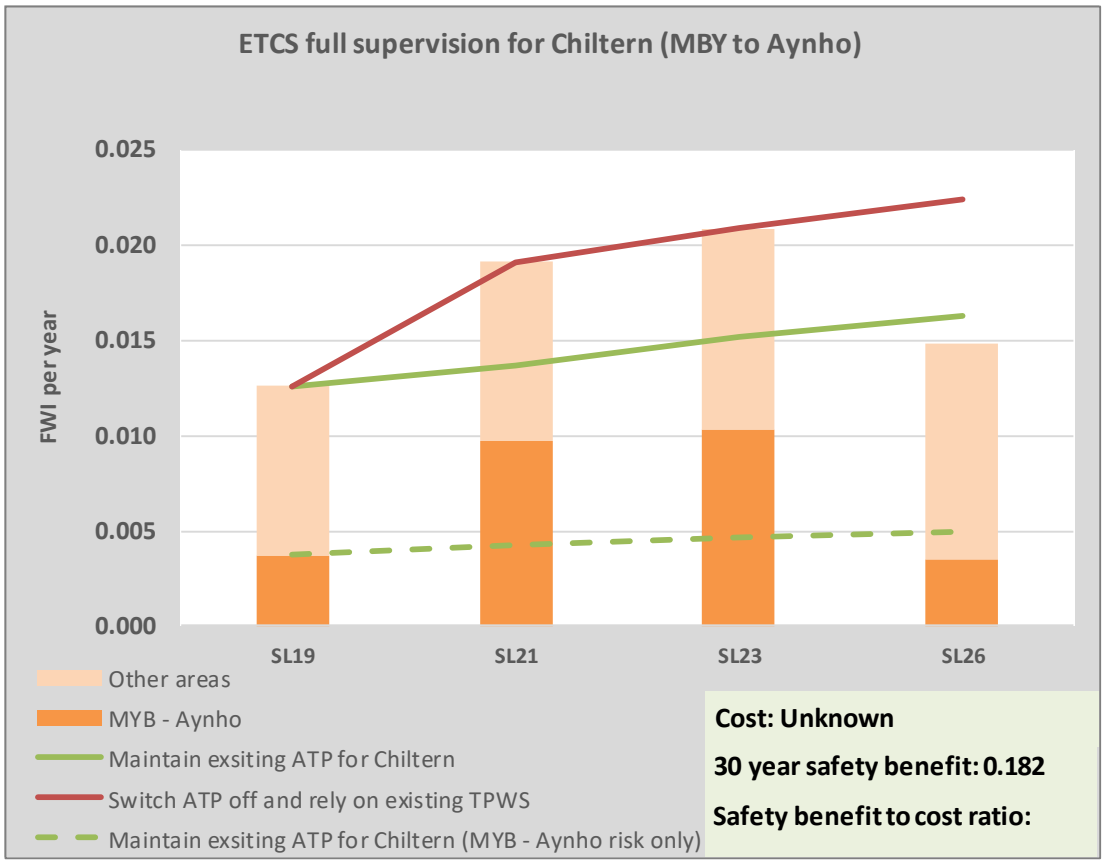
Conclusion: Whilst this option could deliver long term safety benefits, the uncertainty with the timescales of TPWS Mk5 and the possibility that the trials are not successful mean that it is not a viable option to address the short-term issue of ATP obsolescence.

Furthermore, the additional cost of enhanced TPWS lineside between Marylebone and Aynho Junction would be highly cost inefficient as most of the benefits would accrue for only about three years before the ETCS L2 Limited Supervision is implemented. Hence, this option is not recommended for progression as part of the overall Chiltern train protection strategy.

Option 9: ETCS full supervision for Chiltern (Marylebone to Aynho Junction)

Safety: In the long term, this option provides the highest level of train protection and therefore delivers a small risk reduction compared to the current ATP deployment. In the interim period before implementation there would be a significant increase in safety risk due to the degradation of ATP (see *Figure 9*). The chart assumes that the option would be deliverable by the end of 2026; in practice this may not be the case as discussed below.

Figure 9 Train accident risk for Option 9



Operational performance: It is assumed that the operational performance of ETCS would be comparable to, or an improvement on, the existing ATP system.

Cost: The estimated trackside equipment costs are £130m. The cab fitment costs are at least £100k per cab and 130 cabs would need fitment. Hence the overall cost would be at least £143m.

Some of Chiltern Railways' cabs have a short remaining design life such that it would be inefficient to install ETCS to them.

Deliverability and uncertainty: The system is deliverable, however, the timescales would have to be accommodated into a wider strategy for system-wide implementation. The whole area signalling and GSM-R would need to be upgraded in order to facilitate the implementation of

ETCS. Hence, the timescales are too long and too uncertain to manage the critical issue of the obsolescence of the ATP system.

Impact on other parties: The impact on other parties would be minimal as the section between Aynho Junction and Marylebone is largely single operator.

Alignment with business objectives: This option has good alignment with business objectives as it fits with the long-term strategy to roll-out ETCS across the network. However, there is no migration strategy to transition from the existing ATP technology to ETCS.

Regulatory position: This option may meet the requirements of RSR 1999, however, the interim period would be without a fully functioning ATP system and therefore an exemption to cover the interim period would be required.

Conclusion: Whilst this option could deliver long term safety benefits, the long duration before it could be implemented does not address the short-term, critical, issue of ATP obsolescence. Furthermore, as a measure to replace ATP, the costs of the system are grossly disproportionate to the safety benefits. Hence, this option is not recommended for progression as part of the short term plan to address ATP obsolescence. The long-term industry strategy is, however, to have ETCS on the route.

3.2 Conclusion from the assessment of strategic options

From the review of options against the selection criteria, there is only one option that meets the following criteria:

- Maintaining or reducing the risk for the route that is currently protected by ATP between Marylebone and Aynho junction.
- Maintaining or reducing the risk for the entirety of the routes over which Chiltern Railways operates.
- Can be delivered with reasonable certainty by the end of 2023, by which time there is likely to be significant degradation of the existing ATP system.
- Enables a migration that should not detrimentally impact Chiltern Railways, or other operator, services.
- Fits with Network Rail's strategy to transition from a railway protected with TPWS to one protected by ETCS.
- Has a **relatively** favourable benefit to cost ratio (note the ratio is 0.012, but this is a higher ratio than other deliverable options).

This option, Option 5, includes:

- The provision of enhanced lineside TPWS between Marylebone and Aynho junction to latest standards and providing TPWS at plain line signals by 2023.

- Upgrading the Chiltern Railways' cab TPWS units to Mk4, which have protection against TPWS 'reset and continue' events following SPADs as well as continuous health monitoring by 2023. This element of the safety benefit pervades across all Chiltern Railways' services and over all the main line infrastructure they operate.

- Providing rollback protection for cabs that operate over London Underground infrastructure.

The introduction on any future strategy will have to manage the issue of the potential failures of the trainborne ATP units prior to the implementation of enhanced lineside and trainborne TPWS. This is the subject of *Section 4*.

4 ASSESSMENT OF THE IMPLMENTATION PERIOD

The recommended option of enhanced lineside TPWS fitment (Marylebone to Aynho junction) and upgraded cab TPWS units to Mk4 for Chiltern Railways can be delivered through a rolling programme. It is estimated that the programme can be delivered in the period between 2021 to the end of 2023. During this period, there will be a changing, and potentially increasing, level of risk. To manage the risk, it is intended to maintain the operation of ATP (as much as is practical) until the end of 2023 when the programme is complete. In the transition period the following factors will influence the level of risk:

- The progressive failure of the trainborne ATP system. For the purposes of this assessment it is assumed that from 2020, approximately 20% of cabs per year would have failed ATP systems and rely on their TPWS. This is considered a realistic, worst case scenario.

- The rollout of the TPWS lineside upgrades will commence in 2021 and fit 33.3% of the signals per year, starting with the higher risk end of the line (Marylebone) and progressively working north towards Aynho junction.

- The Chiltern Railways' cab upgrade will prioritise stock that are not ATP fitted and are thus currently relying on TPWS.

The last two points of the strategy will minimise the potential for a risk increase in the transitional period.

The results of the assessment are shown in *Figure 10*.

As can be seen from the chart, there is a minor increase in risk for the three-year period 2020 to 2022 (the orange bar is above the green line), before the long-term trend for a moderate risk reduction is achieved from 2023. This risk increase can be managed to an extent in the interim period by:

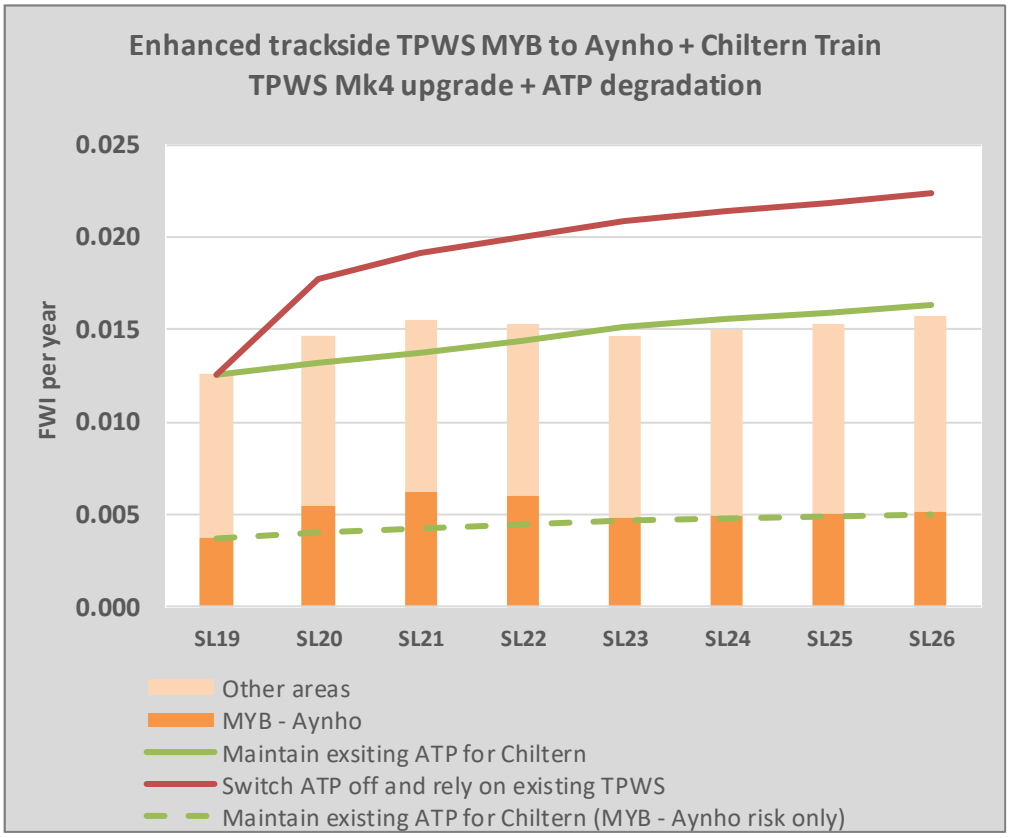
- Maintaining as much of the ATP stock as possible.

- Prioritising the cab upgrades so that the TPWS fitment addresses the stock that has Mk1 TPWS and no ATP.

- Prioritising the lineside upgrade at the higher risk locations.

- Optimising the deployment of the fleet to ensure the ATP stock has the highest utilisation on the higher risk route sections where ATP is provided lineside so long as this does not significantly impact train performance.

Figure 10 Year-by-year assessment of risk



5 CONCLUSIONS AND RECOMMENDATIONS

A wide range of potential future train protection strategies have been analysed in detail to determine the optimum strategy to address the issue of obsolescence of the existing ATP system for Chiltern. These options were appraised using detailed risk assessment and application of agreed option selection criteria. The assessment concluded that there is only one option that meets the following criteria:

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

This Option 5, which includes:

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

This option, as with all options assessed, shows a risk increase in the interim period before the new train protection system is fully operational. Hence the following controls are recommended to help manage the risk during the rolling programme of upgrades:

- Maintaining as much of the ATP stock as possible.
- Prioritising the cab upgrades so that the TPWS fitment addresses the stock that has Mk1 TPWS and no ATP.

- Prioritising the lineside upgrade at the higher risk locations.
- Optimising the deployment of the fleet to ensure the ATP stock has the highest utilisation on the higher risk route sections where ATP is provided lineside.

6 ACRONYMS AND ABBREVIATIONS

Acronym	Description	Comments
ALARP	As Low As Reasonably Practicable	
ATP	Automatic Train Protection	
ETCS	European Train Control System	
ETCS L2 Limited Supervision	The ETCS Limited Supervision referenced in this report is not the Limited Supervision mode defined in ETCS standards. The term is used to describe a method of train protection where the aspect of approached signals are communicated to the train. A modified version of TPWS (termed TPWS Mk5) would apply the train brakes if the speed profile of the train exceed that required to stop the train at the signals that are being approached. TPWS Mk5 is not yet available and would need significant development.	
EWR	East West Rail	
FWI	Fatalities and Weighted Injuries	A measure of safety performance where the predicted rate of fatalities and minor and minor injuries are combined into an overall measure of risk.
NTC	Level National Train Control	An ETCS operational level that permits trains to operate under the management of ETCS, but applying the legacy national train control (for the purposes of this study, AWS and TPWS).
OSS	(TPWS) Over-speed sensor system	
OTMR	On-Train Monitoring Recorder	
SPAD	Signal Passed at Danger	

Acronym	Description	Comments
SRM	Safety Risk Model	The rail risk model managed on behalf of the industry by RSSB
TSS	(TPWS) Train Stop System	
TPWS	Train Protection and Warning System	