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Train Protection and Warning System Project

Submission to Her Majesty's Railway Inspectorate (HMRI): Exemption From TPWS Requirement for Speed Restrictions of a Temporary Nature

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Exemption Request: Summary

1. This document explains Network Rail's request for an Exemption from the requirement established in the Railway Safety Regulations: 1999 (the Regulations) to fit Train Protection and Warning System (TPWS) at certain speed restrictions of a temporary nature.

2. Network Rail has fitted TPWS to the signals on the network that are required by the Regulations to mitigate against the risk of trains colliding at junctions. Network Rail has also installed TPWS at certain buffer stops and at certain 'permanent' speed restrictions. We have now considered the fitment of TPWS to control the speed of trains on the approach to and through 'temporary' speed restrictions.

3. The Regulations define *temporary speed restrictions* as those that are in place for no longer than 3 months and are used in accordance with special procedures by the infrastructure controller. Such temporary speed restrictions are not required by the Regulations to be provided with a train protection system. However, the industry applies the same special procedures to temporary speed restrictions in force for greater than 3 months, and it is this latter class of temporary speed restriction to which this Exemption request applies. For convenience this application refers to such speed restrictions as TSRs.

4. We have investigated the risk of overspeed derailments at TSRs, and our assessment is that the risk is very small. The last fatal train accident at a TSR was in 1975 (Nuneaton). From available records (dating from 1990), there have only been a further 2 overspeed derailments at TSRs, both involving freight trains and probable inappropriate permitted speed or TSR marking. It has been estimated that about 25% of overspeeding events take place at TSRs, with >75% of these being on average 8mph over the permitted speed.

5. From our experience and knowledge from fitting TPWS to prevent overspeed related incidents, we can see considerable technical difficulties and costs in fitting TPWS on the approach to these TSRs which are normally only in force for relatively short periods of time. Network Rail believes that it has a duty to make HMRI aware of these matters, and to seek an Exemption from the Regulations for the work.

   The basis of our Exemption request is as follows:

   (1) The safety benefits from using TPWS to mitigate the risks from Signals Passed At Danger (SPADs) are estimated at 2.3 EF/year, and are already starting to be delivered.

   (2) TPWS is, within its design limitations, an effective system for mitigating SPAD risk. It is inherently less effective as a system to mitigate overspeeding risk.

   (3) The risk of overspeed derailments generally is small (in the range 0.03 to 0.3 EF/year) and is falling steadily because of modern measures that prevent and mitigate overspeeding.

   (4) The proportion of that risk at TSRs is even smaller (in the range 0.003 to 0.09 EF/year) because there are already effective risk control measures.

(5) TPWS is likely to be of particularly limited effectiveness at TSRs. The best we believe TPWS could achieve, if fitted, is to reduce the already small overspeeding risk by an estimated 0.026 EF/year, using long term average risk but based on the TSR numbers in place during 2002.

(6) However, the increase in risk to trackside workers of installing and recovering the TPWS equipment may negate the small safety benefit from TPWS at TSRs.

(7) There are particular practical difficulties in fitting TPWS at certain TSRs because of the requirement for a temporary interface with the signalling system etc. Any interface to safety critical signalling circuits has the potential to increase risk to safety, and cannot be supported by Network Rail for the potentially very small safety benefit available at TSRs.

(8) If the standard rail industry criteria for assessing the safety benefits for TSRs fitment with TPWS were now applied, the work would not show adequate benefit to justify proceeding. The value of preventing a fatality associated with fitment in accordance with the Regulations would lie in the range £87 million to £12.3 billion.

(9) We are seriously concerned that using TPWS at TSRs could erode Driver confidence in TPWS generally, and thus erode the substantial safety benefits of the entire TPWS programme. These concerns are shared by the train operating companies.

(10) We are also concerned that the on going requirement for design, installation, testing and removal of TPWS at TSRs will reduce the availability of Signalling Technicians to take corrective action when signalling and/or TPWS fails.

6. Network Rail has consulted with train operators on this matter. The response from train operators, and the Association of Train Operating Companies (ATOC), was to express concern about the effect that fitting TPWS at TSRs is likely to have on Driver confidence in TPWS as a whole. This may result in Drivers disregarding valid TPWS interventions when signals are passed at danger by resetting the TPWS on the train and continuing into a dangerous situation. Some responses from the train operators state that only long term TSRs (in place for longer than 1 year) should be fitted, but a greater number of train operators and ATOC said that no TSRs should be fitted.

7. Network Rail fully accepts that the management of TSRs is essential to provide safe railway infrastructure and to minimise train delay, and considerable effort is being made to reduce the numbers and duration of TSRs. Fitment of TPWS to TSRs will not benefit the management of TSRs but will add to the management and engineering task.

8. Network Rail is keen to progress this application for Exemption with HMRI, and will fully participate in any industry consultation that HMRI considers appropriate, to ensure that the best interests of users of the rail network are met.

9. Network Rail requests Her Majesty's Railway Inspectorate grant a certificate of permanent Exemption from the Regulations for train protection requirements at all speed restrictions of a temporary nature that are on Network Rail controlled infrastructure.

Contents

1. Introduction

1.1 The Railway Safety Regulations: 1999 (the Regulations) require railway organisations to fit an appropriate train protection system to mitigate risks due to Signals Passed At Danger (SPADs), buffer stops collisions and overspeeding at certain speed restrictions. The Regulations specify circumstances in which fitment is required, with the intent of ensuring coverage of the most significant risk locations on the network. The only currently available system that meets the requirements of the Regulations is the Train Protection and Warning System (TPWS), so that the Regulations in effect mandate situations in which TPWS must be fitted to the railway.

1.2 The Regulations define *temporary speed restrictions* as speed restrictions which are in place for no longer than 3 months and used in accordance with special procedures established by the infrastructure controller. Temporary speed restrictions under this definition are not required to be provided with train protection within the Regulations.

1.3 The Railway Group definition of temporary speed restrictions (TSR) (GK/RT0038) is 'a speed, less than the permissible speed, applied for a pre-planned period not normally exceeding 6 months'. Historically some TSRs have been in place for longer than 6 months. Network Rail is committed to reducing the number and length of time that TSRs are in place as demonstrated in the Network Rail 2003 Technical Plan Section 10 'Operational Performance', which states that one of the assumptions for performance improvement is a reduction in TSRs.

1.4 Therefore, the Regulations treat temporary speed restrictions which are in place for greater than 3 months in the same light as permanent speed restrictions, and thus consideration of train protection is required for this class of TSR.

1.5 This document presents and explains Network Rail's request for an Exemption from the requirements of the Regulations for temporary speed restrictions in place for greater than 3 months, which meet the Regulations' criteria for speed on approach (60mph or greater) and speed reduction (one third or greater). The basis of our Exemption request is that:

a) the safety risk at TSRs is already very small and adequately controlled,

b) TPWS would be of limited effectiveness in controlling this particular risk,

c) there are particular practical difficulties involved in using TPWS for this purpose, and;

d) Driver confidence in TPWS may decline due to spurious intervention, so that there is an increased risk that Drivers will not follow correct procedures when TPWS has made a valid intervention at a SPAD.

1.6 As an indication of the annual TPWS fitment requirement, there were 4950 TSRs imposed during 2002 and 251 of these were such that the Regulations would be applied (in place for greater than 3 months with approach speed 60mph or greater and a one third or greater reduction in speed). In addition, there were 74 such Regulated TSRs in place in 2001 which continued throughout 2002. Thus it is anticipated that around 250 TSRs would require TPWS fitment per year with around 325 in place in any 12 month period.

1.7 The exemption would also avoid the dilution of signalling technician resources and so reduce the effectiveness of their response to signalling and other infrastructure failures.

1.8 Network Rail previously submitted an exemption application for the fitment at TSRs – RMD1/TPWS/REP/526 'Submission to Her Majesty's Railway Inspectorate (HMRI) – Exemption of Temporary Speed Restrictions (TSRs) from the Railway Safety Regulations: 1999'. Since submitting that Exemption application, more analysis on the use of TPWS at TSRs has been undertaken, however, the basic argument is the same but more factors have been considered and we have a greater understanding of the risk involved due to ongoing research since the previous submission. This application for Exemption for TPWS at TSRs (RMD1/TPWS/REP/648) supersedes the previous submission, and Network Rail wishes to withdraw the earlier application.

1.9 In this document we explain what TPWS is and its use in risk reduction (Section 2), the effectiveness of TPWS at TSRs (Section 3), and cost benefit analysis for fitting TPWS (Section 4). We show the practical issues arising from the consideration of fitting TPWS to TSRs (Section 5). We describe the responses to our consultation exercise (Section 6). We draw conclusions (Section 7), on which we base our request for the Exemption to be granted (Section 8).

2. TPWS and its Use for Risk Reduction

2.1 To understand the issues surrounding this Exemption request it is necessary to understand what TPWS is, and its use in protecting against collision and derailment risks on the railway. The following sections describe TPWS and how it works, then discusses its use and effectiveness in mitigating a) collision and b) overspeed derailment risks.

2.2 We also describe the similarities and differences in risk control for different sorts of speed restriction, before expanding on the particular characteristics of TSRs. We then consider what proportion of the derailment risk at speed restrictions is associated with TSRs.

About TPWS

2.3 The Train Protection and Warning System (TPWS) was developed in the early 1990s under the sponsorship of British Rail and then Railtrack. It is a British invention designed to fill a gap between the railway of the 1990s (equipped with automatic warning system, AWS) and the railway of the future (equipped with Automatic Train Protection systems, ATP). AWS, TPWS and ATP are automatic systems designed to protect trains. We explain in outline what is involved in AWS and ATP and then

TPWS itself so that the similarities and differences of TPWS to/from each can be appreciated[1].

2.4 AWS has been in use on British and other countries' railways for several decades. It is installed on all trains and at most signals. It works via a pair of magnets on the track, one a permanent magnet and the other an electromagnet. The pair of magnets is on the approach to each signal, and linked to the signal. The electromagnet is energised only when the signal is green (clear), and both magnets are detected by a receiver on the train. The system on the train warns the Driver, via a horn in the Driver's cab, if the electromagnet is de-energised (i.e. if the signal ahead is showing a red "stop" or yellow "caution" aspect). Following acknowledgement of the horn by pressing a button in the cab, the visual indicator in the cab displays the fact that the Driver has received and acknowledged the state of the AWS trackside equipment. If the Driver does not acknowledge the AWS warning, the system automatically applies the brakes and stops the train. The system also indicates to the Driver via a bell in the cab if the electromagnet is energised (i.e. if the signal ahead is green "clear"), no acknowledgement of this status is required and the cab indicator therefore displays that the electromagnet was energised.

2.5 AWS significantly contributed to the reduction in risk of collisions and derailments in the late 20th century, but major collisions such as those at Southall and Ladbroke Grove have occurred either because the AWS system on the train was not working at the time, or because the Driver cancelled the AWS warning and carried straight on without proper braking.

2.6 ATP is used on many modern high speed railways in developed countries. It incorporates more comprehensive speed and position measurement technology and, like AWS, links into the signals so that the system "knows" the status of the line ahead. ATP continuously monitors the speed of the train against that permitted which can be either intermittently updated or continually updated. A computer determines whether the train is going too fast, and automatically applies the brake if that is the case. The Driver cannot over-ride the brake application. ATP thus avoids the problem of Drivers cancelling AWS warnings without taking appropriate action, though it shares the same problems of reliance on correct signalling of the route ahead, and on proper functioning of the train and infrastructure equipment.

2.7 Trials of ATP took place in Britain following the Clapham Junction accident in 1988. British Rail (BR) and then Railtrack carried out extensive analysis and consultation into whether ATP should retrospectively be fitted to the railway system. The conclusion was reached that the cost and risks of retrofitting were prohibitive in relation to the related safety benefits. It was also relevant that within a decade or two, high speed railways in the UK were expected to come within the scope of European standards for advanced train management (now known as the European Railway Train Management System - "ERTMS"), which incorporates full ATP functionality. Any benefits of

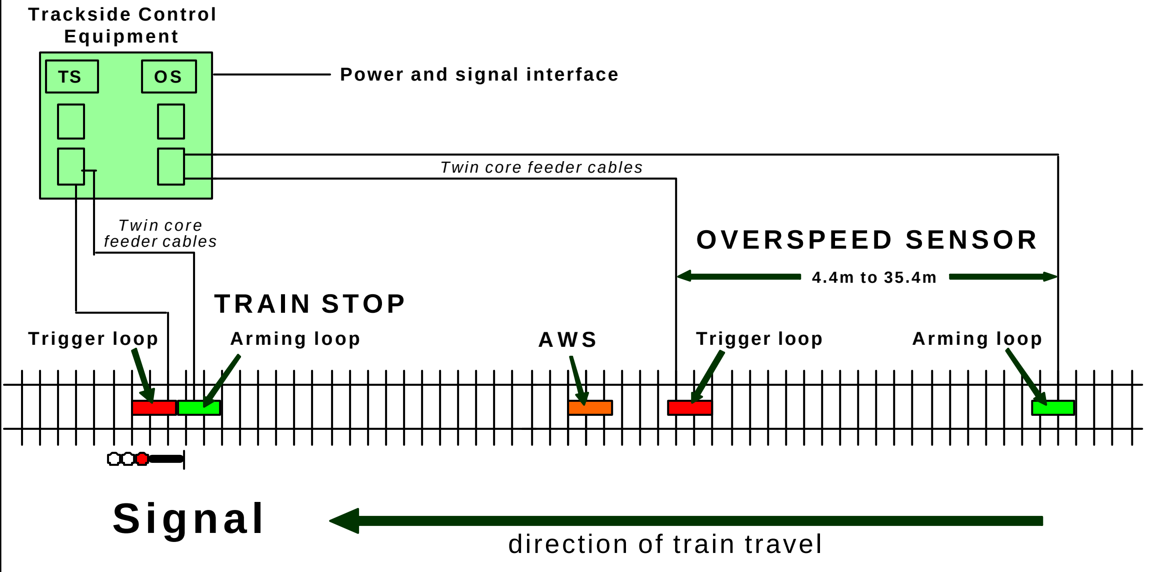
[1] This section provides a condensed summary of the current state of train crash protection systems; a more complete account can be found in the Cullen/Uff Joint Inquiry report.

retrofitting ATP systems would thus have been enjoyed only for a limited period, after which a further expensive transition to ERTMS might have been involved.

2.8 Having decided not to fit ATP retrospectively, but effectively to incorporate it into future systems, BR and Railtrack then sought interim solutions to mitigate ATP-preventable risks, in particular those associated with Drivers failing to stop at red signals or signals set at danger. These circumstances are referred to as "Signals Passed At Danger" (SPADs). A major SPAD reduction and mitigation programme (SPADRAM) was launched, leading to various initiatives to prevent and mitigate SPADs, of which TPWS was a significant part.

2.9 TPWS, like AWS, involves devices on the track, and an antenna on the train to detect those devices. The track devices, called "loops", are used in pairs, of which the first "arms" the system on the train and the second then "triggers" a brake application if required. Two functions are provided by the system, a Train Stop System (TSS) and an Overspeed Sensor System (OSS), as illustrated in Figure 1, and explained below.

Figure 1: Typical TPWS fitment



2.10 To provide a train stop function, the pair of loops is laid close together on the track, close to the signal. Any movement of a train over the train stop loop when the signal is set at danger will trigger a brake application irrespective of speed. Although the train stop does not stop the train on the approach to the signal, the signalling system does have a safety distance (overlap) beyond the signal before a point of conflict. The safety distance however is not sufficient in all cases to prevent collision.

2.11 The overspeed function is provided to apply the brakes on the train if it is approaching a red signal too fast, thereby increasing the likelihood of a train stopping within the safety distance. However it is speed dependent and therefore does not apply the train brakes if the train speed is below the set speed of the particular OSS.

2.12 The intervention of TPWS due to a SPAD or an overspeed is automatic. The train Driver has no warning until the TPWS system activates the brakes. Once activated, the Driver has a flashing indication of the TPWS intervention. The emergency brake will remain on until the Driver has acknowledged the intervention by pressing the AWS reset button, after which the TPWS indicator will turn to a steady indication and the brake will release one minute after the brake was applied. The train Drivers' instructions require the Driver to bring the train to a stand if the TPWS brake application has not already done so, to contact the Signaller, and that the train should be moved only with the permission of the Signaller.

2.13 The new equipment on trains that is specific to TPWS consists of:

- an aerial fitted under the train which picks up the signal from the loops fitted to the track;
- a control unit which activates the brakes if a SPAD or an overspeed is detected (this incorporates the previous AWS control box);
- a Driver's control unit containing;
  - a train stop override;
  - TPWS isolated or faulty indicator;
  - TPWS brake demand indicator;
- a temporary isolation switch;
- wiring which connects the control unit to the aerial, brakes, alarm, indicators and switches.

2.14 The functions of TPWS enable it to be used to mitigate the two types of train accident risk mitigated by ATP. These are collisions due to SPADs, and derailments due to excessive speed. The former currently represents a much larger risk than the latter (though this was not the case until a few decades ago), and has accordingly been the subject of most of the debate and scrutiny of TPWS to date. How TPWS works in each case, how much risk it is addressing, and how effective it is in mitigating that risk, is addressed in the following sections. It should be noted that TPWS is a much simpler system than ATP, and does not mitigate as much of the risk. Its purpose was and is to provide an interim solution that could be fitted much more quickly than ATP, and would provide a substantial proportion of (but not all) the risk reduction benefits.

2.15 The advantages and disadvantages of TPWS in relation to ATP and ERTMS have been extensively debated following the collisions at Southall and Ladbroke Grove. The strategy of using TPWS as an interim measure has been broadly supported for several years and has been a main element of rail industry safety strategy since at least 1996. The Health and Safety Commission introduced the Railway Safety Regulations in 1999 to accelerate its introduction. The Regulations require a programme of fitting TPWS at all locations with specified characteristics (including the fitment of TSRs in place for longer than 3 months and with an approach speed of 60mph or greater and a speed reduction of one third or more) no later than 31 December 2003.

2.16 Unlike TPWS fitments to date, the specific category of speed restrictions that are the subject of this application for Exemption are of a transitory nature and will be dynamic through the life of TPWS as a system. Therefore, fitment and removal of TPWS to such speed restrictions would be on-going until TPWS is replaced by some other train protection system.

2.17 We refer to signals that require fitting with TPWS in accordance with the Regulations as 'regulated signals' and the TPWS fitments required by the Regulations are known as 'regulated fitments'. The programme to fit TPWS in accordance with the Regulations is known as the 'regulated programme'. There are some situations where we are fitting TPWS where it is not required under the Regulations. These fitments are referred to as 'non-regulated'.

Use of TPWS for Collision Protection (SPAD risk)

2.18 Experts have argued for some years over the exact scale of the risk preventable by ATP, but agree that SPADs account for the greater part of that risk. Rail Safety and Standards Board (RSSB) has estimated that the current SPAD risk involves a fatal accident about every two years, with expected casualties averaging 3-4 per year, without TPWS (see Figure 4).

2.19 The main risk from a SPAD involves a train failing to stop within the safe "overlap" beyond a signal set at danger and then colliding with another train. TPWS will not prevent trains going past a signal set at danger, but it does apply the brakes if the Driver approaches it too fast or passes it at danger. In many cases this will stop the train before it reaches a point where it could possibly collide with another train, but this will not always be the case. In particular:

- the maximum approach speed for which typical TPWS installations can be considered fully effective is about 75 mph, and
- the system is most effective for trains able to brake at 12%g, which some train types are not designed to achieve even in good adhesion conditions.

2.20 The main effect of TPWS is thus to mitigate, rather than to prevent SPADs. The Regulations require TPWS to be fitted at all signals protecting points of conflict for the purpose of SPAD risk mitigation. This requirement brings about 11,000 signals within its scope.

2.21 The extent to which SPAD risk will be mitigated by adoption of the regulated programme of fitment has been the subject of much discussion, but is generally considered to be between 60% and 70%. That residual SPAD risk arises from the following:

- speeds above the limit where TPWS will be fully effective;
- trains that cannot brake at the 12%g on which TPWS is predicated or where the lack of rail adhesion prevents this;
- situations in which a Driver might slow down for an overspeed sensor, then speed up again and pass a signal set at danger at significant speed;

- The failure of the TPWS system to provide the positive track/train interaction to apply the train brakes due to equipment faults, unlike ATP where the motion of the train in relation to permitted track speed can be constantly monitored;
- other signals not within the scope of the regulated programme (there are about 28,000 signals on the network, of which about 11,000 fall within the scope of the Regulations for SPAD mitigation).

2.22 Progress across the rail industry against the programmes of TPWS fitment developed to meet the Regulations has been good. Train operators are in the final stages of completing the train fitment programme for equipment on their trains. Fitment of the track loops continues to make good progress. The current state of fitment of the network is illustrated in Figure 2[2].

Figure 2: Current Extent of Fitment of TPWS on the Network *(31 Aug 2003)*

What	Total No. to be fitted	% fitted
Passenger trains	4657	98%
Signals	10,807	97%
RETB Stop Boards	220	0%
PSRs	1,181	51%
Buffer Stops	651	95%
ALL INFRASTRUCTURE	12,859	91%

2.23 The benefits of TPWS can be assessed by considering the changing pattern of SPADs, and their severity. SPAD severity is ranked as follows:

1. Overrun did not exceed 25 yards
2. Overrun between 26 and 200 yards with no damage or casualty
3. Overrun > 200 yards or overrun > signal overlap, no damage or casualty
4. Track damage only, no casualty
5. Derailment with no collision and no casualty
6. Collision (with or without derailment) and no casualty
7. Injuries to staff or passengers with no fatalities
8. Death of staff or passengers

[2] Note in Figure 2: because a stop board is a fixed sign rather than a signal, it has been necessary to develop special equipment to work with it. These fitments are now in progress.

2.24 Experience in the use of TPWS for SPAD risk mitigation has so far been very positive. Up to 19 July 2003, there had been 73 interventions where TPWS had acted correctly in the absence of Driver action to brake a train involved in a Category A SPAD. On investigating these SPADs we see that, on at least one occasion, the system has prevented an almost certain serious collision between two trains.

2.25 In the 17 periods ended Period 04 of 2003/04 there were 829 Cat A SPADs at signals within the TPWS fitment programme. 224 of these SPADs happened when TPWS was commissioned both at the signal and on the train. In the other 605 cases where a SPAD occurred TPWS was not commissioned at the signal and/or on the train. The distribution of SPAD severity category within the two groups is compared in the graph in Figure 3.

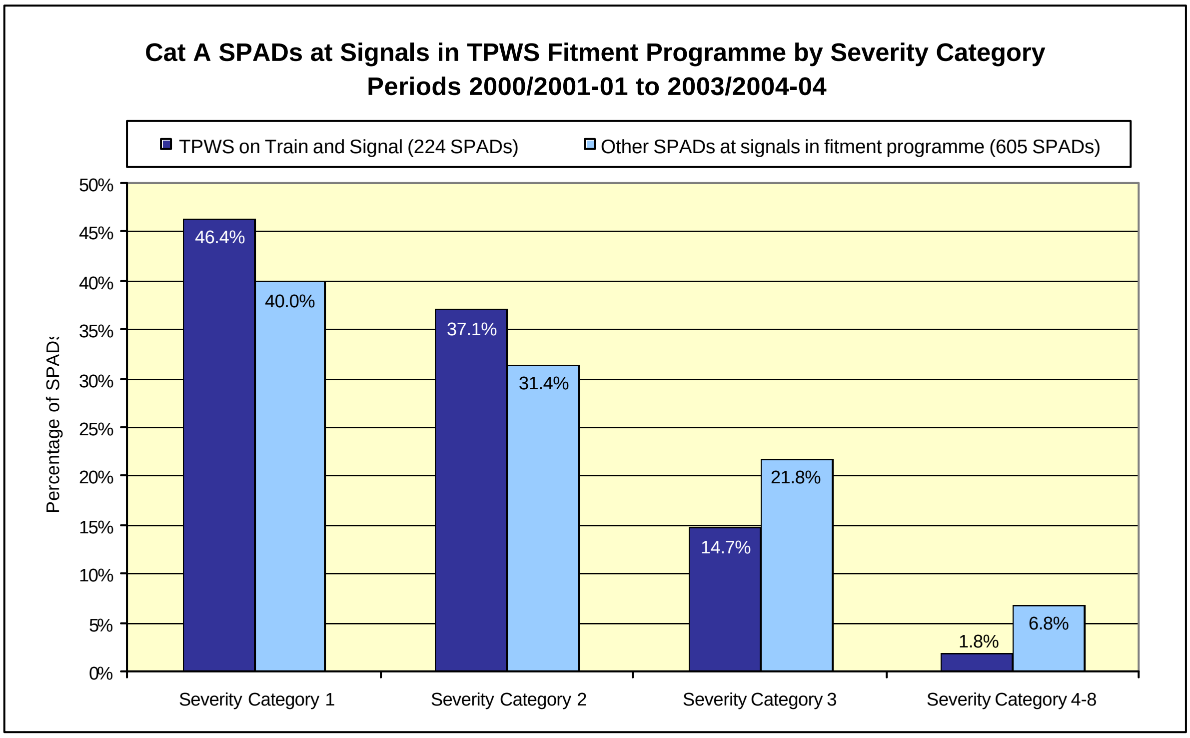


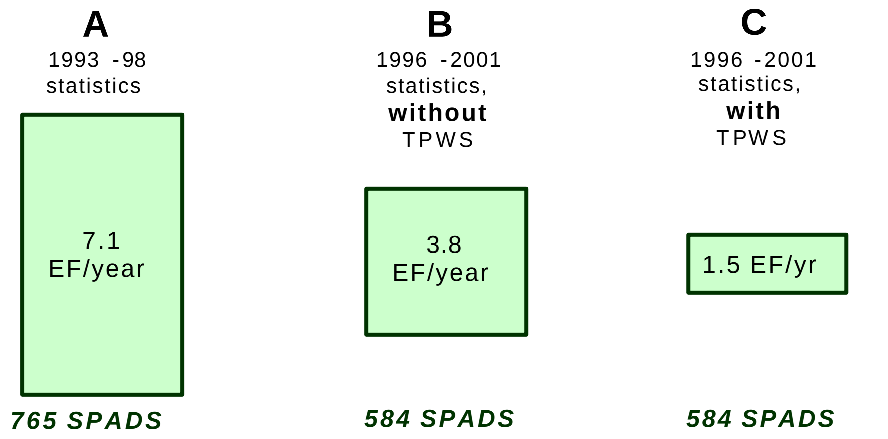
Figure 3

2.26 It can be seen that the proportion of high severity SPADs (3-8) is lower where TPWS is commissioned both at the signal and on the train. In particular there has been more than a 70% reduction in the proportion of severity 4 to 8 SPADs with TPWS and more than 30% reduction in severity 3 SPADs. As would be expected by a shift in mode, there has been a corresponding rise in the proportion of severity 1 SPADs (+16%) and severity 2 SPADs (+18%). It can be inferred that TPWS is turning high severity SPADs into low severity ones, as intended (in category 1 and 2 SPADs the train stops in the safety overlap) with a small reduction in overall numbers.

2.27 Given the good progress on the installation of TPWS, and the developing record of its effectiveness in mitigating the effects of SPADs, there is confidence across the rail industry in the ability of the system mandated by the Regulations to mitigate a majority share of the SPAD risk on the network. The other very satisfactory trend over the past two years has been reduction in the numbers of SPADs. This is mainly attributable to many other initiatives taken by train operators, Network Rail and its industry partners to improve Driver responses still further, improve signal sighting, etc. However, in some instances TPWS has been able to prevent a SPAD from occurring. The size of the SPAD risk that the regulated TPWS programme is addressing has thus shrunk considerably, as illustrated in Figure 4.

2.28 Figure 4 is based on the Risk Profile Bulletins published by RSSB. Each block illustrates (to scale) the magnitude of the collision risk due to SPADs, in terms of expected average annual equivalent fatalities. The left most block (A) is predicated on the rate of occurrence of SPADs and the average consequences per SPAD over the period 1993-98, which were used to validate RSSB's Safety Risk Model (SRM – contains a detailed analysis of different types of SPAD and their causes and consequences). The results were normalised for the volume of rail traffic (passenger and freight train kilometres per year) at the time of publication of the Bulletin in July 2001.

Figure 4: SPAD Risk & Changes



Source: Railway Safety Risk Profile Bulleti

2.29 The centre block (B) in Figure 4 is predicated on the rate of occurrence of SPADs and the average consequences per SPAD over the period 1996-2001, again used to validate the SRM, and re-normalised for the volume of rail traffic today. The right hand block (C) represents the result of an analysis carried out by RSSB, who re-estimated each segment of SPAD risk using the SRM, under the hypothesis that the regulated programme of TPWS fitment had been completed.

2.30 There is also, though, growing awareness of operational limitations on the effectiveness of TPWS, in particular associated with Drivers' confidence in the system. Of the 73 correct interventions of TPWS to stop a train during a Category A SPAD up to 19 July 2003, there have been 9 instances in which the Driver, thinking that TPWS had incorrectly stopped the train, then cancelled the system. In most cases this involved switching off the Driver's controls and then switching back on, or acknowledging the intervention and waiting a minute or so for TPWS to clear; and then setting off again into potential danger. The Drivers in these instances did not comply with the Rule Book to contact the Signaller and get permission before moving the train. These incidents are regarded with the utmost seriousness within the industry, and there are a number of initiatives underway by Network Rail, RSSB, the ATOC and the individual train operators to resolve this problem.

2.31 These incidents demonstrate that TPWS effectiveness depends critically on Driver confidence in the system. The system will always reset after the Driver acknowledges an intervention, and there have to be operational work arounds available in the event of the system failing safe and stopping a train. Anything that increases the actual or perceived rate of spurious actuations of TPWS erodes Driver confidence and increases the risk that such work arounds will be used when they should not be.

2.32 Impairment of the very substantial benefits of the regulated TPWS programme in terms of SPAD risk reduction (around 2-3 lives saved per year, even with the lower rate of SPADs now prevailing) by erosion of Driver confidence is something we aim to manage assiduously as experience with TPWS develops. This is a potentially significant issue in the use of TPWS for overspeed derailment protection, in particular TSRs. Experience with the fitting of TPWS at certain 'permanent' speed restrictions has been identified as a potential cause of loss of confidence in the system. The application at TSRs, which are more complex to design, is likely to increase this further.

2.33 The compliance of train Drivers with their instructions when TPWS intervenes is relevant for all TPWS fitments, not just TSRs. The work that the industry is undertaking to resolve this matter is therefore not specific to TSRs. So, while this is an important consideration for this Exemption application, we would not expect HMRI to delay consideration of this application until the matter is resolved.

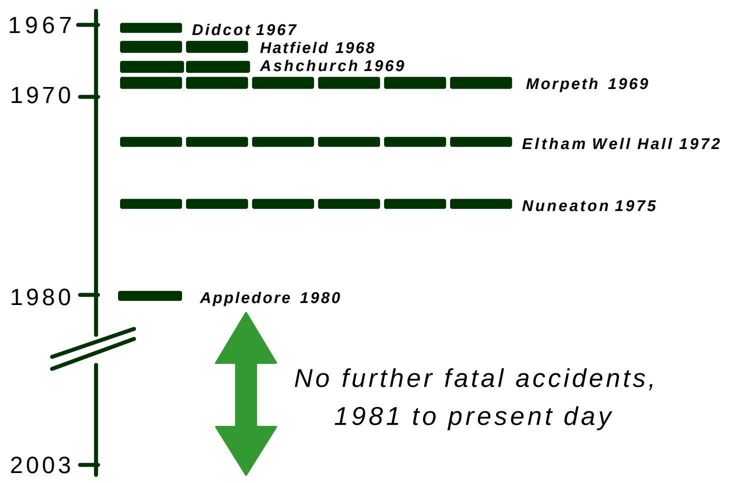
Use of TPWS for Derailment Protection (Overspeed risk)

2.34 Overspeeding on straight track does not of itself create significant risk, as most trains will remain stable even at well above their maximum attainable speed. On curves, though, there is a risk that significant overspeeding could lead to trains leaving the track. Seven fatal accidents have happened through this cause in the last 35 years, as shown in Figure 5[3]. The most recent such fatal accident was at Appledore in 1980, more than 20 years ago.

2.35 To prevent overspeeding on curves and in other places where it might be hazardous, permanent speed restrictions (PSRs) are imposed on the network. Other speed restrictions are temporary (TSRs), and are imposed because of track condition, for example. Emergency speed restrictions (ESRs) sometimes have to be imposed at short notice if an incident or natural event occurs that creates a sudden new hazard. Where such specific speed limits do not apply, all railway track has a 'linespeed' that is the maximum permitted speed.

[3] "Fatal Train Accidents on Britain's Main Line Railways: End of 2001 Analysis", Prof. A W Evans, University College London, March 2002.

Figure 5: Fatalities in Overspeed Derailments since 1967



2.36 The risk of derailment due to excess speed is virtually entirely associated with various speed restrictions, and not with sections of track where trains run at maximum permitted speed.

2.37 Figure 5 allows the risks associated with overspeed derailments to be viewed over many decades, and suggests a decline in the risk of serious overspeed derailments, based on data from fatal accidents. The availability of accurate data for injuries does not extend this far back in time, although RSSB is planning to collate data and validate historic data on accident injuries.

2.38 Complete data for accident injuries is available from 1990, and this data has been analysed. However, it is apparent from the data available on fatalities that the risks associated with overspeed derailments are reducing, which is not surprising, as the controls in place to prevent and mitigate overspeeding have evolved considerably over that period.

2.39 Using TPWS to mitigate against overspeeding involves use of the overspeed sensor, rather than the train stop TPWS device. This involves placing a pair of loops on the track before the speed restriction (as shown in Figure 1 earlier). The TPWS timer on the train is set to a fixed interval for all passenger trains. Another, slightly longer fixed interval is used for all freight trains. The distance between the loops thus determines the set speed above which TPWS will be triggered by the second loop. That set speed is higher for passenger than for freight trains. Once the loops have been placed on the track, the speed above which TPWS will work has been set and cannot be adjusted for different types of train or conditions. For example, if the loops are set for a passenger train speed of 70 mph, then any passenger train going faster than this will cause TPWS to apply the brakes. Any passenger train going slower will be unaffected.

2.40 It is important not to apply the emergency brake on trains braking normally on the approach to a speed restriction. This raises an immediate dilemma as to what the set speed should be, and where the loops should be placed. To safeguard the fastest trains, the loops would ideally be well back from the speed restriction and set for a high speed, to give maximum time for the train to slow down. To safeguard lower speed trains, though, the loops would need to be nearer to the speed restriction and set for a lower speed. The System Concept that we have agreed with the industry, and then formalised with HSE, was to focus on the highest risk, and so the high speed traffic at each speed restriction. This has become a fundamental principle in the design of TPWS installation for speed restrictions. This means that all but the highest speed traffic is not protected when TPWS is used purely as an overspeed protection device.

2.41 An overspeed sensor is much better for SPAD protection because the set speed can be assessed on the assumption that all trains approach in a defensive manner hence it is set to lower speeds than an equivalent speed restriction installation.

2.42 The safety function provided by TPWS as an overspeed device is thus qualitatively different from that as a SPAD mitigation device. TPWS will always intervene to apply the brakes in a SPAD incident, though its effectiveness in stopping the train within the particular safety distance (overlap) depends on the train's brake capability, the safe distance past the signal, and the speed and rail conditions at the time. TPWS will not always intervene to apply the brakes in an overspeed incident at a speed restriction; it will only do so for the high speed traffic selected as the basis for setting up the system. The other factors that limit TPWS effectiveness in SPAD mitigation all apply also to its use for overspeed protection. TPWS is thus inherently significantly less effective as an overspeed protection than as a SPAD mitigation system.

2.43 When we devised our programme for meeting the Regulations, we decided to tackle signals first and speed restrictions later, as a) SPADs represented a bigger safety risk, and b) we would then have more experience in fitting TPWS to bring to bear on the technically more challenging problem of speed restrictions.

2.44 We began surveying the PSRs sites where TPWS is required to be installed, and designing specific installations, in 2002. We became increasingly aware via our production staff involved in devising the schemes of the inherent limitations to its effectiveness, and of concerns about its effect on Drivers. In parallel, our staff and contractors carrying out surveys, designs and installations were advising us of significant practical issues (which translate into higher costs and less effectiveness) to do with establishing designs for and then fitting TPWS at speed restrictions. In particular:

a) The process for deciding the right set speed is complex; it involves collecting a lot of detailed information about the approaches to the restriction including gradient, other speed restrictions and combining this in a spreadsheet programme. We require the results to be checked and authorised by a senior signal engineer.

b) In addition, for speed restrictions in complex areas once the design and set speed are decided, there are significant site-specific practical issues to be addressed, associated in particular with the need to switch TPWS on and off depending on which route is set.

2.45 All of these factors apply equally to TSRs.

2.46 To understand the risks arising from trains overspeeding through TSRs we have analysed the available data on the risks and trends associated with overspeeding on the network. The findings of this work are shown in Appendix 1. From the analysis we draw the following conclusions:

1. There has been a steady and continuing downward trend in the risk of overspeeding leading to derailments extending through the past decade as well as over previous decades.
2. Evidence for this trend is supported by examination of broader trends in the numbers of derailments generally, and of derailments associated with Driver error in particular (See Appendix 1, part A2).
3. This trend is consistent with progress in the measures to improve management of overspeeding risks introduced during the period considered. The measures include:
   a) introduction of lineside speed signing (post 1945);
   b) introduction of radar speed checks (10-15 years ago);
   c) fitment of Advanced Warning Boards and AWS permanent magnets on the approaches to severe PSRs and TSRs (15 – 25 years ago);
   d) drug & alcohol abuse changes (last 10-20 years, in society as well as the railway);
   e) improved Driver selection processes and competence management systems (last 10 years);
   f) introduction of train data recorders (last 10 years), and;
   g) formal introduction of defensive driving training & policies (last 10 years).
4. The current risk of all fatal derailments due to overspeed is difficult to estimate, but is in the range of one accident every 20-200 years, leading to on average 0.03 to 0.3 equivalent fatalities[4] per year.
5. The effectiveness of TPWS in mitigating overspeed derailment risk at speed restrictions is significantly less than that at mitigating SPAD risk.

2.47 Additionally, there are significant practical issues associated with using TPWS at speed restrictions, linked particularly to the need for site-specific surveys and design work and to the need to interface to the signalling system in certain circumstances. Any link to the signalling system itself introduces safety risk as more demand is placed on the primary signalling safety system.

[4] Equivalent fatalities take account of major injuries and minor injuries.
Equivalent fatalities=fatalities + 0.1x major injuries+0.005x minor injuries.

2.48 Also, there are significant stakeholder concerns associated with:

- the safety risks to track staff,
- the response of Drivers who may find TPWS intrudes more on normal driving practice at speed restrictions than it does at signals set at danger leading to loss of confidence in the system as a whole.

2.49 Figures 6 and 7 below show summary "pyramids" of TPWS-addressable risks and the wider set of less severe related events, for derailment and SPAD risk respectively as quantified by our analysis. These figures show that the greatest share of safety benefits from the regulated TPWS programme will come from SPAD risk mitigation, and not from overspeed protection at speed restrictions.

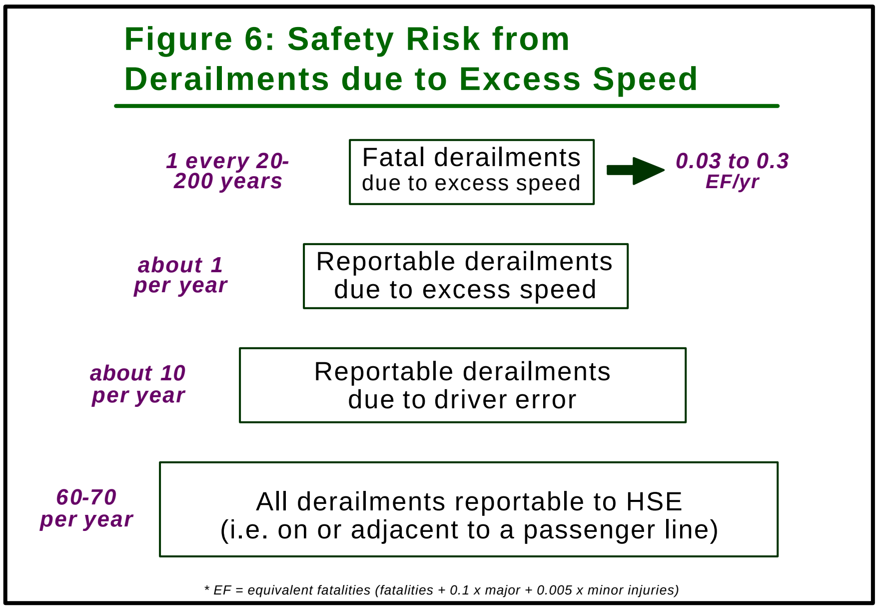


Figure 6: Safety Risk from Derailments due to Excess Speed

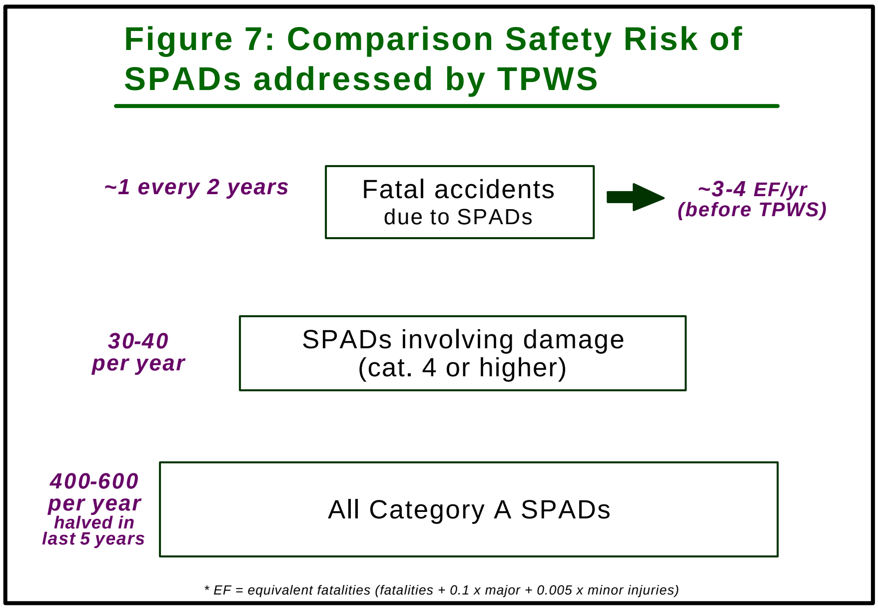


Figure 7: Comparison Safety Risk of SPADs addressed by TPWS

2.50 Given the concerns raised already about Driver response to TPWS at speed restrictions, and the importance of Driver confidence to maintaining the whole of the safety benefits of TPWS (in SPAD mitigation as well as for overspeed protection), we have a general concern about the use of TPWS as an overspeed protection device at speed restrictions, based on:

- the relatively very low overspeeding risk being addressed;
- the general limited effectiveness of TPWS in reducing that risk;
- the potential for unintended interference with Drivers' normal practices at speed restrictions, which could erode their confidence in (and thus a significant proportion of the benefits of) the whole TPWS programme;
- connection of temporary equipment to safety critical signalling circuits.

2.51 We are therefore concerned that TPWS should be applied with care at speed restrictions generally. We believe that there are regulatory requirements for TPWS fitments where we can demonstrate that the benefits of fitment arising from improved safety are outweighed by the increased safety risks of installation, the high cost of fitment and the practical difficulties of applying TPWS.

2.52 We next discuss the TSRs which are the subject of this Exemption request.

3. TPWS Effectiveness at TSRs

Control of Overspeeding at Speed Restrictions

3.1 The purpose of speed restrictions generally is to slow trains down so that they provide a comfortable ride, do not create undue wear, and do not derail. PSRs are used particularly to protect against derailment owing to overspeeding on curves (including through diverging junctions). TSRs are imposed for many circumstances including mitigation of derailment risk as a result of the condition of the track or the track support system.

3.2 For a derailment to occur at PSRs, trains need to be travelling considerably in excess of the permitted speed. A derailment risk exists at a typical tolerance of 50% above the permissible speed (e.g. for a permitted speed of 40 mph, the risk of derailment would only exist above 60 mph; there are many examples of much higher overspeeds, up to 150%+, not leading to derailment). In order for derailment to occur, the train therefore needs to exceed the permitted speed very significantly.

3.3 The level of overspeed at TSRs where risk of derailment is high could be significantly different to that for PSRs dependent upon the reason for the restriction. Therefore, there might be a need for a bespoke design for the positioning and separation of the loops dependent on the nature of the hazard being controlled. Any reductions on the 50% overspeed margin will by definition reduce the effectiveness of TPWS.

3.4 PSRs are learnt by Drivers along with the basic track layout and signalling when they learn a route. PSRs are indicated by lineside signs that are visible from the Driver's cab and details are published in the Network Rail Sectional Appendices issued to each

Driver. Those PSRs in the scope of the Regulations are also provided with an AWS permanent magnet to provide an audible warning to the Driver and apply the brakes if not acknowledged (at approach controlled signals the AWS magnet at the cautionary signal fulfils this role), and with an advance warning indicator (AWI), which is an extra lineside sign advising the train Driver of the speed restriction sign ahead.

Existing protection provided by TSRs

3.5 The requirements for the application of TSRs are contained within the Railway Group Standard GK/RT0038'Signing of Permissible Speeds and Speed Restrictions' and are summarised below.

3.6 Existing TSR protection consists of a warning board situated at a distance in rear of the commencement of the TSR equivalent to the full service braking distance for trains approaching at the maximum permissible speed (adjusted for gradient). The warning board contains information relating to the permitted speed through the TSR and, where the TSRs applies only to one route(s) of a divergence(s), a directional arrow(s). Different speeds may be indicated for different classes of train.

3.7 A permanent AWS magnet is sited 183 metres in rear of the warning board to alert Drivers to the presence of the warning board (Note: in certain circumstances this may be provided by disconnecting an existing signal AWS electro-magnet).

3.8 A TSR speed indicator is sited at the beginning of the TSR to display the maximum permitted speed and a termination indicator is mounted at the end. In certain circumstances, e.g. where a station exists between the warning board and speed indicator, a repeating warning board is also required.

3.9 The TSR is published in the Weekly Operating Notice (WON) so that Drivers are aware of the TSR prior to working over the affected portion of the route for the first time.

3.10 At any speed restriction, then, in order to derail the train through overspeed, the Driver would have to:

- forget and/or ignore the instructions and briefings given in advance;
- ignore speed signs on the approach to and at the speed restriction;
- acknowledge and then ignore the AWS alarm; and
- exceed the permitted speed by the required safety margin.

Proportion of Overspeed Risk at TSRs

3.11 When considering what proportion of the network-wide risk is associated with TSRs it is necessary to examine historic serious overspeed derailment incidents. The fatal accidents since 1967 and the track circumstances in which they occurred are summarised in Table 1.

3.12 One of the fatal derailments (at Nuneaton in 1975, accounting for 6 of the 24 fatalities in the period) involved a TSR. An important additional overspeed mitigation introduced at TSRs since that accident is the use of an AWS magnet (installed by a

Track staff the day the TSR is imposed) to provide additional warning for Drivers approaching a TSR.

Location	Year	Fatalities	Track Circumstances
Appledore	1980	1	Crossover 20 mph (not TSR)
Nuneaton	1975	6	TSR
Eltham Well Hall	1972	6	Curve 20 mph (not TSR)
Morpeth	1969	6	Plain line PSR (80mph over 50mph PSR)
Ashchurch	1969	2	Plain line track twist (not TSR)
Hatfield	1968	2	Over-run (not TSR)
Didcot	1967	1	Crossover 25 mph (not TSR)

Table 1: Fatal Overspeed Derailments since 1967

3.13 There have also been a number of non-fatal derailments since 1990 details of which have been extracted from the Safety Management Information System operated by the RSSB, the Derailment Investigation Service operated by AEA Technology (formerly BR Research), and Network Rail Regions. A summary of these various reports (including insights from HSE incident reports where incidents were reportable to HSE) is provided in Table 2.

3.14 Table 2 reveals that, where the 'line situation' could be deduced only 2 of the 23 incidents took place at TSRs. Both of these TSR incidents occurred at relatively low speed and there were question marks over whether the speed restriction was appropriate, or appropriately marked. Both incidents also involved freight trains, for which TPWS offers even less effectiveness.

3.15 In one of these two incidents, and in 4 out of the 9 incidents at all types of speed restrictions (PSRs as well as TSRs), the overspeeding behaviour occurred within or on exit from the speed restriction, not on the approach to it where TPWS equipment would be located.

3.16 Also, the safety risk for the derailed train is higher for incidents where trains approached speed restriction too fast than for those where overspeeding occurred within the speed restriction (compare Skelton Bridge, Morpeth, Maidstone East – all of which involved overturning parts of the train – with Effingham Junction, Longannet, Manchester, Knutsford which did not).

3.17 While overspeeding within a speed restriction, rather than on the approach to it, is perhaps less likely to lead to casualties on the train involved, it can still obstruct another line (as indeed did all four such incidents since 1990.

3.18 By examining individual detailed reports of a large sample of overspeeding incidents, see Appendix 2, it has been possible to ascertain the speed control regime in force (PSR, TSR, line speed etc) where each incident occurred, and to analyse the distribution of permitted speeds and excess speeds involved. The analysis has revealed the following detail.

Date	Location	Reports available			Train type	Line Situation	Notes
		HSE	SMIS	Detail (1)			
31.7.90	Chelford	N	Y	NN	Freight	Running line	Wrong direction movement caused derail
21.5.92	Effingham Junction	Y	Y	YN	Mk 1 Psgr (empty)	PSR	Derail at 46 mph in 70 mph due to lateral pressure on track over bridge - after leaving 20 mph PSR at 38 mph one chain earlier
17.2.93	Longannet (Torryburn)	N	Y	NY	Freight	TSR	Train travelled at approx line speed (35 mph) over a 10 mph TSR imposed 5 Feb (condition of track); note NO lineside markers were present
22.2.93	Plumley	N	Y	NY	Freight	Running line	Estimated speed 53 mph at derailment within track section of PS 45 mph for this train
13.4.93	Townhill	Y	N	YY	Freight	TSR	Driver drew power while travelling at 20 mph within 20mph TSR; described as "not at fault" (implying TSR insufficient for risk control?)
3.9.93	Grove Park (Main Line)	N	Y	NN	ECS multiple	Siding(2)	No details (presumably minor incident)
6.9.93	Maidstone East	N	Y	NY	Freight	PSR	Estimated 55-60 mph (speed needed to overturn wagons) in 35 mph PSR
23.9.93	Manchester Piccadilly	Y	Y	YN	Light loco	PSR	Loco travelling at 30 mph over 15 mph PSR on departure from platform at station
19.4.94	Dartford	N	Y	NN	ECS multiple	Siding(2)	Excess speed (prob 25mph+) entering sidings; driver admitted to 15 mph (speed limit not known)
27.6.94	Morpeth	Y	Y	YY	Parcels/ mail	PSR	Estimated 80 mph over 50 mph PSR on Morpeth Curve (75 mph min speed needed to overturn train)
4.10.94	Didcot Parkway	N	Y	NN	Light loco	Siding(2)	Loco derailed all wheels due to excess speed on entering yard
28.11.94	Kirkland East	N	Y	NN	Freight	Running line	Derailed on points (excess speed, + failure to examine setting of hand points)
14.3.95	Elsham	Y	Y	YY	Freight	Running line	Travelled at 40-48 mph over uneven track with permitted line speed 35 mph
24.7.95	Skelton Bridge	Y	Y	YY	Parcels/ mail	PSR	Travelled at 50-60 mph over 30 mph PSR either side of bridge (est. from speed to overturn train)
13.12.95	Shoeburyness	Y	Y	YN	ECS multiple	Running line	Derailed entering depot, with rear of train obstructing main line
27.1.96	Cwmgwrach	Y	N	NY	Freight	PSR?	Train did not stop at mandatory stop board. Derailed on facing points; speed > 20 mph limit
6.10.98	Newton Heath DMU Depot	N	Y	NN	ECS multiple	Siding(2)	Combination of excess speed & poor rail condition
17.2.99	Tyseley No.1	N	Y	NN	Freight	Siding(2)	Derail due to sharp brake application at low speed
8.3.99	Newton (WCML)	N	Y	NN	ECS multiple	Siding(2)	Braked too hard at buffer stop in icy conditions
22.6.99	Barry Dock	N	Y	NN	???	???	No details at all in SMIS record (presumably a minor incident)
29.6.99	Knutsford	Y	Y	YY(4)	Freight	PSR	Probably overspeeded by 2-3 mph either within line speed sections (45 mph) or within a 40 mph PSR on part of route within which derail occurred
6.10.99	Wigan Wallgate	N	Y	NN	ECS multiple	Siding(2)	Primary cause was points not properly set; overspeed a minor factor
10.3.02	Oxenholme	N	Y	NN	Freight	Running line	Within possession; exceeded the 2 mph speed limit imposed by on-site engineer

Notes: (1) 1st letter relates to availability of SMIS full text report, 2nd to BR Derailment Investigation Service (now AEAT) report except see note (4)
(2) "Siding" includes any other depot or yard situation
(3) Although TPWS would be fitted at Morpeth under the Regulations, it would be set to trap full line speed passenger trains (125 mph) and would not have trapped this train, travelling at under 90 mph.
(4) The 2nd "Y" here refers to availability of a Network Rail NW Zone internal report, not the Derailment Investigation Service report

Table 2: Non-Fatal Overspeed Derailments since 1990

3.19 The main significant findings are that most (>75%) overspeed incidents in SMIS are logged via the programme of radar speed checks carried out by train operators and Network Rail, and involve modest average excess speeds (about 8 mph on average).

3.20 Also, a minority (<25%) of overspeed incidents that are reported by railway staff (typically Signallers or track staff in the vicinity of the speeding train) who do not have means of accurate speed measurement; such incidents thus tend to be reported only when the excess speed is large.

3.21 The programme of radar speed checks probably includes a disproportionately high sample of TSRs, as these are among the situations which train operators or Network Rail are more likely to monitor, and hence does not attempt to sample a statistically significant "slice" of the network. Thus it is considered that no deduction can be made as to the overall incidence of overspeeding on the railway from this data.

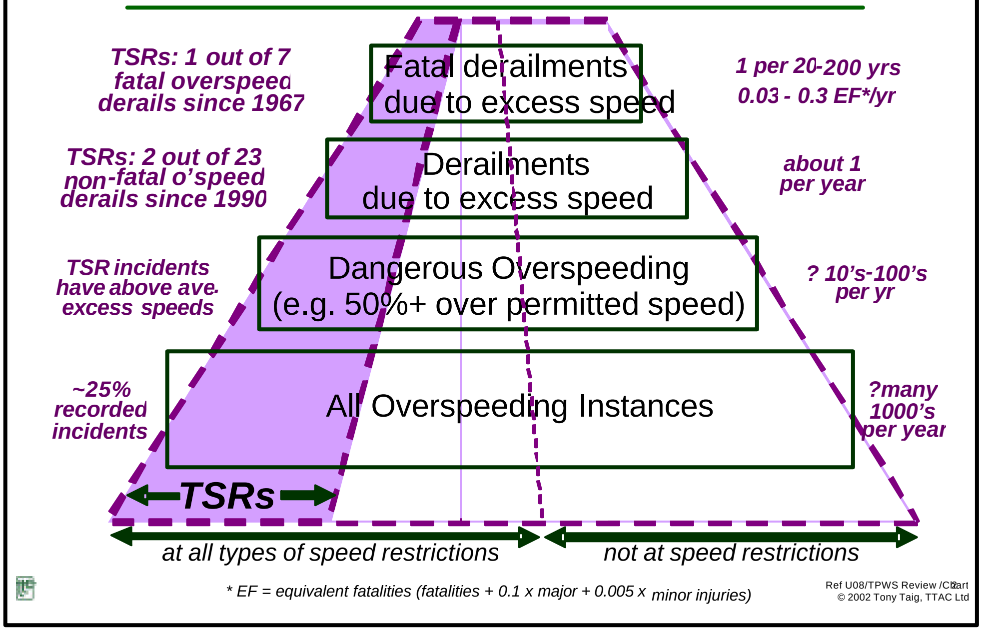
3.22 Having made all these provisos, about 25% of reported overspeed incidents are at TSRs.

3.23 High excess speeds in relation to permitted speed are rarer for higher line speeds.

3.24 Very severe overspeeding incidents are rare but, such incidents are likely to be reported if there are rail staff in the vicinity of the speeding train, but unlikely to be reported by Drivers. As train data recorders become more prevalent, train operators are increasingly able to check that this is the case by examination of sample train data recorder evidence.

3.25 A summary of what can be deduced from all of the above about the proportion of overspeed derailment risk associated with TSRs is illustrated in Figure 8 below. Information about "all overspeed derailment risk, network wide" is on the right hand side; information relevant to TSRs is on the left.

Figure 8: Overspeed Derailments – Safety risk, precursors & TSR elements



3.26 The overall estimate is that somewhere between 10% and 30% of network-wide overspeed derailment risk is associated with TSRs.

3.27 The basis for the higher estimate is that there is clearly evidence that overspeeding at TSRs can lead to derailments, and that TSRs are about 25% of reported overspeeding incidents generally, and among the fatalities that have occurred in overspeed derailments in modern times (since 1967). Also, TSRs appear to involve above average excess speeds compared with other reported overspeed incidents, though this may owe more to which incidents get monitored and reported than to a real difference in Driver behaviour. There is a fundamental difference between a PSR and a TSR here in terms of human factors. A PSR is part of the route knowledge training, so the Driver always expects to slow down. Thus it is only if the Driver "gets disorientated" that serious overspeeding occurs at a PSR. A TSR is not logged in this manner so there is a risk of "forgetting". This risk is largely covered by the AWS warning and the signage provided.

3.28 The lower estimate is based on the fact that TSRs have accounted for about 10% of non-fatal derailments since 1990, albeit that neither of those incidents represented a serious safety risk linked to excessive approach speed. It could be argued that the introduction of AWS as an additional risk control measure at TSRs has been particularly effective in dealing with overspeed on the approach to TSRs, particularly when the TSRs have only recently been put in place.

3.29 The final point in connection with TSRs is that we have very recent experience (post Hatfield) of very large numbers of TSRs being put in place on the network, with no associated experience of major increases in reported overspeeding or derailment incidents. This tends to support a conclusion that overspeed risk at TSRs is not large as a proportion of overall overspeed risk.

3.30 The best estimate of the total network-wide risk of derailments at TSRs is thus 10-30% of 1 fatal overspeed incident every 20-200 years, or about 1 fatal overspeed incident every 60-2000 years, or 0.003 to 0.09 EF/year.

Distribution of Risk at TSRs

3.31 This section considers the distribution of overspeed risk at TSRs in time and space within the TSR, and across different types of trains.

3.32 Where (physically) the risk of overspeed derailment occurs at TSRs is critically important in relation to TPWS effectiveness. This is because TPWS can protect only against overspeed at a single location on the approach to the TSR. It cannot protect against Drivers speeding up once that point has been passed, whether within or in rear of the TSR itself.

3.33 While it is not possible to estimate with any precision what proportion of the risk is linked to different times and places within TSRs, some important and very relevant observations can be made based on the non-fatal overspeed derailments summarised in Table 2. Table 3 shows some additional information about these derailments, relating in particular to where and when the derailment occurred, and to some of the factors that influence derailment consequences.

Table 3: Risk Factors for Non-Fatal Overspeed Derailments post-1990

Date	Location	Train type	Line Situation	Notes	? O'speed on approach	On or blocking psgr line?	Factors relevant to risk/consequences	Within scope of Regs?	TPWS preventable?
31.7.90	Chelford	Freight	Running line	Wrong direction movement caused derail	N	Y	Other line blocked	N	N
22.2.93	Plumley	Freight	Running line	Estimated speed 53 mph at derailment within track section of PS 45 mph for this train	N	Y	minor	N	N
28.11.94	Kirkland East	Freight	Running line	Derailed on points (excess speed, + failure to examine setting of hand points)	Y	N	minor	N	N
14.3.95	Elsham	Freight	Running line	Travelled at 40-48 mph over uneven track with permitted line speed 35 mph	?	Y	Other line blocked; vehicles overturned	N	N
13.12.95	Shoeburyness	ECS multiple	Running line	Empty train derailed entering depot road at Shoeburyness, with rear cars blocking main line	N	Y	Other line blocked	N	N
27.1.96	Cwmgwrach	Freight	PSR?	Train did not stop at mandatory stop board. Derailed on facing points; speed > 20 mph limit	Y	Y	One wagon overturned	N	N
21.5.92	Effingham Junction	Mk 1 Psgr (empty)	PSR	Derail at 46 mph in 70 mph due to lateral pressure on track over bridge - after leaving 20 mph PSR at 38 mph one chain earlier	N	Y	minor	N	N
6.9.93	Maidstone East	Freight	PSR	Estimated 55-60 mph (speed needed to overturn wagons) in 35 mph PSR	Y	Y	Overturn, Wagons into tunnel on sides	N	N
23.9.93	Manchester Piccadilly	Light loco	PSR	Loco travelling at 30 mph over 15 mph PSR on departure from platform at station	Y	Y	Serious fuel leak; 5 platforms blocked	N	N
27.6.94	Morpeth	Parcels/ mail	PSR	Estimated 80 mph over 50 mph PSR on Morpeth Curve (75 mph min speed needed to overturn train)	Y	Y	Loco + most vehicles overturn; driver injured	Y	N[3]
24.7.95	Skelton Bridge	Parcels/ mail	PSR	Travelled at 50-60 mph over 30 mph PSR either side of bridge (est. from speed to overturn train)	Y	N	Multiple wagons overturned; driver major injury	N	N
29.6.99	Knutsford	Freight	PSR	Probably oversped by 2-3 mph either within line speed sections (45 mph) or within a 40 mph PSR on part of route within which derail occurred	N	N	Other line blocked	N	N
17.2.93	Longannet (Torryburn)	Freight	TSR	Train travelled at approx line speed (35 mph) over a 10 mph TSR imposed 5 Feb (condition of track); note NO lineside markers were present	Y	N	minor	N	N
13.4.93	Townhill	Freight	TSR	Driver drew power while travelling at 20 mph within 20mph TSR; described as "not at fault" (implying TSR insufficient for risk control?)	N	N	One wagon rotated 180^o	N	N
10.3.02	Oxenholme	Freight	Possession	Within possession; exceeded the 2 mph speed limit imposed by on-site engineer	N		minor	N	N
3.9.93	Grove Park (Main Line)	ECS multiple	Siding[2]	No details (presumably minor incident)	?		minor	N	N
19.4.94	Dartford	ECS multiple	Siding[2]	Excess speed (prob 25mph+) entering sidings; driver admitted to 15 mph (speed limit not known)	Y		minor	N	N
4.10.94	Didcot Parkway	Light loco	Siding[2]	Loco derailed all wheels due to excess speed on entering yard	Y		minor	N	N
6.10.98	Newton Heath DMU Depot	ECS multiple	Siding[2]	Combination of excess speed & poor rail condition	Y		minor	N	N
17.2.99	Tyseley No.1	Freight	Siding[2]	Derail due to sharp brake application at low speed	N		minor	N	N
8.3.99	Newton (WCML)	ECS multiple	Siding[2]	Braked too hard at buffer stop in icy conditions	Y		minor	N	N
6.10.99	Wigan Wallgate	ECS multiple	Siding[2]	Primary cause was points not properly set; overspeed a minor factor	N/A		minor	N	N

3.34 Key observations from Table 3 are that 3 of the 9 derailments at speed restrictions involved overspeed within the speed restriction, not on the approach and, only 1 of the 23 derailments involved a train travelling in excess of 60 mph (Morpeth, 1994) and at this incident, TPWS would not have stopped the train if a standard fitment had been made because it would have been set for higher speed passenger traffic and would have allowed through the parcels train travelling at 80 mph.

3.35 Both of the incidents at TSRs appear to have involved poor marking or indication of the TSR, implying that there is a non-zero segment of the overspeed risk at TSRs associated with incorrect setting up of the TSR rather than with Driver behaviour. Associated problems would be revealed earlier in the life of a TSR rather than later.

3.36 It appears entirely consistent with general driving experience, whether on roads or railways, that a non-trivial segment of overspeed derailment risk at TSRs should be associated with overspeed within, or in anticipation of exit from, the TSR rather than on the approach. Arguments for and against a high proportion of risk being associated with the approach are summarised below:

Arguments FOR high proportion of risk on approach	**Arguments AGAINST high proportion of risk on approach**
While some derailments may occur due to overspeed within the TSR, the speed of trains will be lower and consequences less than for the (rarer) high speed approach where the Driver disregards the TSR. Non-fatal derailments (Table 3) suggest that the higher speed and potentially most severe derailments are due to overspeed on the approach.	AWS should be particularly effective in warning Drivers on the approach to a TSR; there is no such control to prevent acceleration once into the TSR. Of the 3 "not approach" non-fatal derailments at speed restrictions in Table 3, two involved very significant movements of wagons away from the line where derailment occurred, that could have put trains on other lines at risk.

3.37 It is assumed that a range of 20-40% in this assessment is the estimate of the proportion of risk thus NOT associated with the approach (i.e. assumed 60-80% of risk is associated with the approach to the TSR).

3.38 As regards when in the lifetime of a TSR the risk is higher or lower, different experienced railway people have different views. One school of thought argues that the risk is highest early in the lifetime of a TSR, when it is unfamiliar to the Driver, and the risk of disregard is greatest. The other school argues that the risk is least when the TSR is new, because the Driver's memory of the Operating Notice will be fresher, the impact of lineside signs will be greater, and in particular because the value of an AWS alarm when the Driver is not expecting it should be very high. The risk might then creep upward toward the levels associated with typical PSRs as the TSR "fades into the background" of route features with which the Driver is familiar, and as he/she becomes more habituated to acknowledging the AWS alarm once it has been given.

3.39 To these arguments needs to be added the additional observation from Table 3, that there appears to be a non-trivial segment of TSR overspeeding risk associated with incorrect setting up of the TSR, rather than with Driver behaviour. Any such problems are likely to be revealed (and lead to risk) early, rather than later, in the lifetime of a TSR.

3.40 It has not been possible either to ascertain this from the incident records, or to cross-reference overspeed and derailment incident information at TSRs back to records of the TSRs themselves to determine when in the lifetime of the TSRs the incidents occurred.

3.41 What appears clear from the non-fatal derailment incident records at speed restrictions (Table 3) is that there is likely to be a significant segment of the risk associated with each of the "early" and the "later" phases of life of a TSR. A range of 30-70% for the proportion of risk associated with the early days of a TSR (i.e. within the first month or so) has been assumed for this assessment.

3.42 Finally, it is clear from Tables 2 and 3 that a large majority of non-fatal overspeed derailments involve freight or parcel, rather than passenger, trains. The RSSB Safety Risk Model,[5] which is based on historical risk experience extrapolated to the best of current ability to today's circumstances on the railway, estimates the following overall levels of derailment risk, and of overspeed derailment risk, associated with passenger and non-passenger trains:

Event Type	Risk Parameter	Passenger Trains	Non-passenger Trains	Total
All derailments	events per year	11.06	54.2	65
	EF per year	3.17	1.76	4.9
All overspeed derailments	events per year	0.0925	0.835	0.93
	EF per year	0.0366	0.0327	0.07

Table 4: Derailment Risk (RSSB) Without TPWS

3.43 Table 4 reflects the much higher propensity of non-passenger trains than of passenger trains to derail, with about 5 times as many derailments annually of non-passenger trains. But the risk is still dominated by the rarer passenger train events, because these include the occasional high speed tragedies such as Hatfield and Potters Bar. Non-passenger train derailments do, though, entail risk for passenger trains because of the possibility that the derailed train will obstruct a passenger line, leading to a collision.

3.44 Moving from "all derailments" to "all overspeed derailments" in Table 4, the proportion of events and of risk is shifted further towards non-passenger rather than passenger trains. While there are estimated to be about 9 times as many non-passenger overspeed derailments, the equivalent fatality annualised risk is about the

[5] "Risk Profile Bulletin", Report No. SP-RSK-3.1.3.11, Railway Safety (now RSSB), February 2003, Table B1 Events:
HET-12 Precursor POSL----PH (Overspeeding leading to passenger train derailment)
HET-13 Precursor FOSL----FH (Overspeeding leading to freight train derailment on passenger lines)
HET-13 Precursor FOSL----NH (Overspeeding leading to freight train derailment on freight-only lines)
HET-13 Precursor FOSL----CH (Overspeeding leading to ECS or parcels derailment)

same for non-passenger and passenger trains. This is compatible with the superior design of passenger train bogies and suspension, which makes them considerably more robust to overspeeding than non-passenger trains.

3.45 As would be expected, given that they are based on the same historic data, these observations are also compatible with the pattern of non-fatal derailments in Table 4. Of 23 non-fatal overspeed derailments since 1990, just one affected a passenger train. Of the 9 overspeed derailments at speed restrictions, none involved a passenger train. It is considered that the distribution of overspeed derailment risk at TSRs likely to be the subject of fitment under the Regulations may well be shifted further towards non-passenger trains than that for overspeed derailments generally. This is because TSRs to be fitted under the Regulations will largely be in place for track defects, to many of which freight trains would be particularly susceptible.

3.46 It appears, then, that overspeed derailment risk at speed restrictions generally, and at TSRs that are required to be fitted under the Regulations in particular, is likely to comprise two significant segments: a) Passenger train derailment risk – associated with rare events (a modest fraction of about 1 every ten years), which are potentially serious (average EF/event about 0.4, from Table 4), and b) Non-passenger train derailment risk – associated with less rare events (a modest fraction of about 1 per year), which are less likely to have severe consequences (average EF/event about 0.04, from Table 4).

3.47 The uncertainty associated with the former set of events is much greater than that with the latter, where we have the corroboration of relatively frequent non-fatal events (as shown in Tables 3 and 4). Extrapolations and models of passenger train events retain very significant uncertainty because the risk involved is dominated by such rare events. While extrapolations of time trends for overspeed passenger derailments and their precursors, and consideration of all the improvements in overspeed derailment risk management in recent decades, suggests that the passenger train risk is much lower than it was historically (towards the bottom end of the uncertainty band is considered for this assessment), it is not possible to verify this from direct historic experience. This justifies using the relatively wide band of estimated "total network-wide overspeed derailment risk" applied in this assessment.

3.48 The effectiveness of TPWS for freight trains is much less than for passenger trains because of the slower approach speed (more likely to be below the OSS trapping speed) and much lower braking performance.

3.49 In taking forward this assessment it is assumed that the passenger and non-passenger elements of overspeed derailment risk are roughly equal in equivalent fatality terms, based on passenger events being about 10 times less likely but 10 times more serious than non-passenger events.

3.50 This passenger/non-passenger split is also relevant to considering the proportion of overspeed risk at TSRs associated with high speed approaches such as would be protected under the Regulations. Based on Tables 2 and 3, it appears that a large proportion of overspeed derailment risk at TSRs is NOT associated with high speed approaches, and that this is an inference that can be made with reasonable certainty.

What is much less clear, and cannot be verified from direct historical incident experience, is the proportion of passenger overspeed derailment risk at TSRs associated with high-speed incidents. For the purposes of this assessment it is assumed that somewhere between half and three quarters of all TSR derailment risk due to overspeeding on the approach is associated with "high speed TSRs" (using the definition under the Regulations – those involving normal passenger permitted approach speed greater than or equal to 60 mph, and an imposed speed reduction of 1/3 or more). The upper (75%) level would imply most of the passenger train risk and about half the non-passenger risk being associated with "high speed" TSRs. The lower (50%) level would imply most of the passenger train risk, and a minority of the non-passenger train risk, being associated with "high speed" TSRs.

TSRs on the Network

3.51 The Regulations require fitment of TPWS at all speed restrictions where the approach speed is greater than or equal to 60 mph and there is a required reduction of 1/3 or more to the permitted speed through the speed restriction, and where the restriction is in place for more than 3 months. When the Regulations were first proposed, we asked for the requirement to fit TPWS at speed restrictions to be waived for various types of speed restriction, including those which are the subject of this Exemption request. In our response, dated 21 August 1998, to the draft Regulations it was stated that we believed it was not reasonably practicable to fit TPWS where the complexity is high and thus the system may be unreliable e.g. speed control for Temporary Speed Restrictions. Our objections were overruled. We did not at that time have the evidence to challenge the Regulations, and we thus accepted our duty to comply. Having now successfully completed the majority of signal fitments required by the Regulations to achieve SPAD mitigation, we are now well placed to assess the technical complexity, safety benefit, and costs of the fitments for TSRs.

Category	Total TSRs (1/02 to 12/02)	TSRs 9/02 to 8/03
Total: all TSRs imposed	4950	4843
All TSRs imposed in 2002 for overspeed derailment protection =>60mph + 1/3 reduction	1806	1668
All TSRs imposed in 2002 >90 days	623	568
All TSRs imposed in 2002 meeting requirement of the Regulations	251	220
Proportion of TSRs that meet the requirements of the Regulations	5%	5%

Table 5: Numbers of TSRs

3.52 Our work to analyse the risks associated with the TSRs commenced in early 2003, and so the base data for TSRs that was chosen for analysis was calendar year 2002. From Table 5 above it can be seen that in 2002 there are 251 TSRs that fall within the scope of the Regulations. This compares with the 11,000 or so signals where TPWS is required to be fitted by the Regulations for SPAD risk reduction and 1,200 PSRs, where TPWS is required to be fitted by the Regulations for overspeed derailment risk and 654 buffer stops to prevent collisions between the train and the buffer stop. Unless otherwise stated, the analysis of TSRs quoted in this submission relates to calendar year 2002.

3.53 To ensure that the data for 2002 TSRs is still relevant, an exercise has been undertaken to assess TSRs on the network during the 13 accounting periods (4 week periods) up to August 2003. Table 5 shows the numbers of TSRs on the network in calendar year 2002, compared with the year up to August 2003. The number of TSRs imposed that would fall within the scope of the Regulations has reduced slightly from calendar year 2002. Therefore, we believe that the analysis undertaken based on the 2002 year is still valid, and if anything slightly overstates the risk currently posed by TSRs. It is worth noting that the rate that the new TSRs have been imposed during the summer of 2003 has been increased. It is too early to establish whether this trend of new TSRs will eventually result in more TSRs that would be subject to the Regulations. Network Rail is committed to reducing the number and duration of TSRs on the Network.

Average Risk per TSR-Day

3.54 In this section historic average levels of TSRs on the network are combined with the estimates from above to estimate levels of risk per day that various types of TSRs are present as follows.

	Average TSR-years present (see 3.55)	Network-wide risk EF/yr	Risk per TSR-yr EF
All TSRs	400-500	0.003 to 0.09	6×10^{-6} to 2×10^{-4}
All "High Speed" TSRs[6]	39% of the above	0.0015 to 0.07	8×10^{-6} to 4×10^{-4}

3.55 The historic average level of TSRs present on the network has been taken as 450 (the long-term average level mentioned in the Network Rail prospectus, which is close to the 459 TSR-years within 2002 attributable to TSRs imposed in 2002). The proportion of TSR-years associated with "high speed" TSRs is taken from Table 5 (i.e. based on the proportion associated with TSRs imposed in 2002).

3.56 The network-wide risk estimate is taken from the above, and the proportion of that risk at "high-speed" TSRs is based on the discussion immediately above.

3.57 Of this "high speed" risk per TSR, it needs to be remembered that only part is in principle addressed by TPWS fitment.

Summary of Overspeed Derailment Risk at TSRs

3.58 The overall network-wide risk of an overspeed derailment at TSRs is about 0.003 to 0.09 EF per year(1 fatal accident every 60-2000 years).

6 "High Speed TSRs" is used henceforth to denote all TSRs where the normal passenger permitted approach speed is 60 mph or greater, and the TSR involves a passenger train speed reduction o f 1/3 or more.

3.59 The average risk per "high speed" TSR is about 8 x 10^{-6} to 4 x 10^{-4} EF per year the TSR is in place.

3.60 Between 60% and 80% is addressable by TPWS by virtue of where in relation to the TSR the risk is concentrated.

Effectiveness of TPWS in Risk Reduction

3.61 The effectiveness of TPWS in reducing overspeed derailment risk at TSRs depends on:

- the proportion of the risk associated with those TSRs to be fitted with TPWS under the Regulations
- the proportion of the risk at fitted TSRs which is reduced by TPWS once fitted, and
- the proportion of the lifetime of each fitted TSR for which TPWS is in place.

3.62 The latter factors are considered in turn in the following sections, before summarising their overall implications for the effectiveness of TPWS in risk reduction.

3.63 It has been concluded from our work on assessing risk at PSRs through diverging junctions with approach controlled signalling, that the effectiveness of TPWS as an overspeed derailment risk mitigation device was low (in the range 5-20%). A major factor was the policy of using the overspeed sensor to trap the highest speed traffic using the route, which means lower speed traffic can overspeed without "tripping" the TPWS equipment. For diverging junctions, a high proportion of traffic (particularly the diverging traffic) runs at a lower speed for which TPWS is ineffective.

3.64 The importance of this is illustrated by the right-hand columns in Table 3, which show in each case whether the line situation would have required TPWS to be fitted under the Regulations and, if fitted, whether it would have been effective in preventing the derailment. The following key points emerge.

3.65 A significant portion of derailment risk is associated with TSRs that would not be fitted under the Regulations. Only 1 of 9 speed restrictions where such derailments occurred would clearly have been required to be fitted – the 8 "not requiring fitment" included two in which wagons overturned, 5 others which obstructed another line, and only one which did neither (this corroborates the point made in clauses 3.11 to 3.30 that fitment of TPWS under the Regulations would only address a proportion of the overall risk due to overspeeding at TSRs).

3.66 In the one instance where TPWS clearly would have been required to be fitted at a speed restriction (Morpeth), it would have been ineffective as the setting would have been designed for the highest speed trains using the route (the 110 mph passenger trains), and the derailed mail train (80 mph) would not have achieved the set speed of the TPWS equipment.

3.67 It is useful to consider the likely effectiveness of TPWS for passenger and non-passenger trains separately. For non-passenger trains, it is particularly unlikely that TPWS will be effective in mitigating risk, because firstly a) a significant proportion of risk is in any case associated with low-speed incidents where TPWS would not have an effect, and b) the trains generally run more slowly than passenger trains, and are thus very likely not to be trapped by speed traps on mixed traffic lines even if they are significantly overspeeding, and c) there are further practical difficulties in making TPWS effective for freight trains, whose TPWS timer is set differently from passenger trains, and d) the braking characteristics of freight trains are generally poorer than passenger trains.

3.68 For passenger trains, a higher proportion of the risk is probably associated with very rare, very high speed approaches to the TSR. There is also a better chance that the train involved will be among the higher speed traffic on the route, and thus that the setting of the TPWS speed trap would "catch" it if seriously overspeeding. On the other hand, the trains best able to withstand overspeeding through a TSR are probably the more sophisticated, higher speed trains, whereas those less able to do so (and thus more likely to dominate the risk in question) will be the lower speed trains which are more likely not to be tripped by the TPWS overspeed protection system. It is also noted that many TSRs have two speeds, a high one for passenger trains and a lower one for freight trains. Only one speed can be protected and it has to be the highest one because of the way TPWS operates.

3.69 Overall, it very unlikely that TPWS will have much effectiveness at all in preventing overspeed derailment risk associated with non-passenger trains. It is expected that its mitigating effect will be less than 10%, and would be very unlikely to be as high as 20%.

3.70 For passenger trains, it is more likely that TPWS will have some beneficial effect. Taking the most optimistic possible view, it might achieve levels of effectiveness broadly similar to those achieved when used as a SPAD mitigation device at signals (60-70%) for routes where there is a single type of traffic and where the speed setting could thus reliably be set to intervene for all trains. In practice, though, most risk at TSRs is likely to be on busier lines with mixed traffic, where it is estimated that perhaps 1/3 to 2/3 of the "best possible on single traffic routes" benefit might be achieved, on average, from a programme of TPWS fitments at TSRs, i.e. providing maybe in the range 20-50% effectiveness.

3.71 Given all the limitations on TPWS effectiveness discussed above, and the approximately equal portions of TSR overspeed risk associated with non-passenger and passenger trains, the best estimate of the proportion of TSR overspeed derailment risk that TPWS would remove, once fitted, is in the range 20-40% of the addressable risk.

3.72 When this is factored together with the portions of the risk that are addressable by TPWS, the overall effectiveness of TPWS, once fitted, appears as follows.

Risk per "high speed" TSR-yr	8×10^{-6} to 4×10^{-4} EF (clause 3.54)
Proportion associated with approach	60 to 80% (clause 3.37)
Proportion mitigated once fitted	20 to 40% (clause 3.71)
OVERALL benefit of fitment	1×10^{-6} to 1.28×10^{-4} EF per TSR/yr

3.73 These estimates can now be factored with either the whole programme of regulated TPWS fitments at TSRs or with individual TSRs to estimate the safety benefit of TPWS fitments. In making a "whole programme" estimate, it has to be borne in mind that only those TSRs of duration greater than 90 days require to be fitted under the Regulations. For 2002, these account for 186 TSR-years out of a total 272 TSR-years associated with "high speed" TSRs (Table 6, column 3), or about 60-70% of the total. A rough estimate of the network-wide benefit of the programme of fitment (based on assessed risk and TSR numbers during 2002) of regulated TSRs can thus be made as follows:

Network-wide overspeed derailment risk at TSRs		0.003 to 0.09 EF/yr (clause 3.30)
x	Proportion associated with high-speed TSRs	50 to 75% (clause 3.50)
x	Proportion addressable with TPWS	60 to 80% (clause 3.61)
x	Proportion addressable risk mitigated by TPWS	20 to 40% (clause 3.71)
x	Proportion high-speed TSR-yrs to be fitted	60 to 70% (see above)
=		1.1×10^{-4} to 1.5×10^{-2} EF/yr

Table 6: Numbers of TSRs in 2002

Category	Total TSRs	Total TSR years (all future time)[1]	TSR-years (ave TSRs present within 2002)[2]	% ALL present any time in 2002	% All Imposed during 2002
TOTAL: all TSRs present in 2002	5946	1468	953	102%	208%
TOTAL: all TSRs imposed in 2002	4950	757	459	48%	102%
All TSRs imposed in 2002 for o'speed derail protection >60mph & 1/3 speed reduction ("Hi-speed TSRs")	1806	272	177	19%	39%
Proportion of TSRs/TSR yrs that are "Hi Speed"	*36%*	*36%*	*38.6%*		
All TSRs imposed in 2002, > 90 days	623	536	230	24%	50%
Proportion of TSRs/TSR yrs that are > 90 days	*13%*	*71%*	*50%*		
All TSRs imposed in 2002, within Regs[3]	251	186	93	10%	20%
Proportion of TSRs/TSR yrs that are within Regs	*5%*	*24%*	*20%*		

future & may be unreliable because conservative (distant) completion dates are held in the TSR database

[2] *Sum of (no. of days each TSR persisted during 2002) / 365*

[3] *Within the Regulations means that the TSRs are in place for more than 3 months and the previous line speed is greater than 60 mph with a one third reduction for the TSR*

3.74 It is estimated that the effectiveness of TPWS is considerably lower than that incorporated into the most recently published RSSB Safety Risk Model results, as indicated by Table 7, which shows the corresponding Safety Risk Model estimates to those in Table 4, adjusted for the effects of a programme of TPWS fitment in line with the Regulations.

Event Type	Risk Parameter	Passenger Trains	Non-passenger Trains	Total
All derailments	events per year	10.79	52.55	63
	EF per year	3.09	1.72	4.8
All overspeed derailments	events per year	0.0653	0.590	0.66
	EF per year	0.0258	0.0231	0.05

Table 7: Derailment Risk (RSSB) With TPWS

3.75 The effectiveness of TPWS implied in the RSSB assessment was of an approximate 40% reduction in overspeed derailment risk, which is a much higher percentage estimate than has been made in this assessment. This is because a) the RSSB assessment covered ALL overspeeding, not just at particular speed restrictions which already have significant additional overspeed protection measures in place, and b) the RSSB assessment used very broad-brush assumptions about TPWS effectiveness, which did not take into account many of the detailed considerations either of the proportion of risk addressable through TPWS, or of the effectiveness of TPWS in mitigating that addressable risk, that have been considered here.

3.76 It is interesting to note that despite the much higher percentage effectiveness of TPWS used in the RSSB assessment, their estimate of the absolute benefits of TPWS fitment are not inconsistent with the upper estimates in this and a previous (certain PSRs) assessment. This is because it is considered that the possibility that the risk being addressed (in particular the component associated with very rare, very high speed approaches to speed restrictions in which the Driver totally disregards the speed restriction and all warnings and controls already in place) might be very much higher than is estimated in the RSSB model, without being inconsistent with the (very limited) actual evidence relevant to such events in today's conditions on the railway.

Time to Fit TPWS

3.77 During the planning process for TSRs, consideration will be given to whether or not TPWS needs to be fitted. In this case, TPWS will normally be provided from the time the TSR is first implemented. However it should be noted that for those TSRs that already exist there will be a period of about 40 days where no protection is provided whilst consideration of whether TPWS fitment is necessary which includes the time to plan, design, install, test and commission the TPWS equipment. This will also be the case where a planned TSR of less than 3 months duration is extended in time to beyond 3 months due to a number of potential factors. For the purposes of this Exemption request, it is assumed that TPWS will be fitted when the TSR is first applied although this will not always be the case in practice.

Summary of the effect of TPWS on TSRs

3.78 The overall estimate of the effect of TPWS in mitigating the risk at TSRs is thus made up as follows:

a) the network-wide overspeed derailment risk associated with TSRs is in the range 1 fatal accident every 60-2000 years (0.003 to 0.09 EF per year, or $6x10^{-6}$ to $2x10^{-4}$ EF per TSR-year) (clause 3.58 – 3.59).

b) the proportion of this risk at "high speed" TSRs is between 50% and 75% (clause 3.50), of which

c) 60% to 80% is addressable by TPWS because it occurs on the approach to, not within TSRs (clause 3.37), of which

d) the proportion that TPWS would mitigate once fitted would be in the range 20% to 40% (clause 3.71).

The key assumptions and conclusions to which they lead are summarised in Table 8.

Table 8: TPWS Effectiveness at TSRs

8 a) Whole-System Parameters & Approx Benefits of Fitment as per the Regulations

Parameter	Index	Lower	Upper	Units	Notes
Overall system-wide risk of overspeeding	A	0.005	0.05	Fatal accidents/yr	c.f. RSSB Safety Risk Model: 0.005 fatal events/yr; 0.05 EF/yr
	B	0.03	0.3	EF/yr	
System-wide risk of overspeeding at TSRs	C	0.0005	0.015	Fatal accidents/yr	This assessment: 10-30% of system-wide o'speed risk is at TSRs
	D	0.003	0.09	EF/yr	
Proportion of TSR risk at hi-speed TSRs	E	0.5	0.75	dimensionless	"Hi-speed" = normal line speed 60 mph or more, and 1/3 or more speed reduction
Proportion of TSR risk at hi-speed TSRs linked to overspeed on approach	F	0.6	0.8	dimensionless	This assessment
Proportion of TSR risk addressable within time-frame for which TPWS could be fitted	G	1	1	dimensionless	ALTERNATIVE ASSUMPTION - all TPWS fitments planned as TSR is planned, so TPWS is in place from 1st moment of TSR
Proportion of TSR risk addressable by TPWS fitment at hi-speed TSRs	H	0.3	0.6	dimensionless	H = E * F * G
Proportion of addressable risk covered by the Regulations (i.e. associated with 90 day + hi-speed TSRs)	J	0.6	0.7	dimensionless	This assessment: based on proportion of TSR-days associated with > 90 day TSRs
Proportion of TSR risk mitigated once fitted with TPWS	K	0.2	0.4	dimensionless	This assessment; depends on a) % traffic that benefits & b) driver behaviour
Proportion of TSR risk mitigated by fitting of TSRs covered by the Regulations, ignoring time required to fit	L	0.036	0.168	dimensionless	L = H * J * K
Total O'S Derail Safety Benefit of fitment as required by the Regulations (ignoring time to fit)	M	1.8E-05	2.5E-03	Fatal accidents/yr	M = L * D
Total O'S Derail Safety Benefit of fitment as required by the Regulations (ignoring time to fit)	N	1.1E-04	1.5E-02	EF/yr	N = L * C

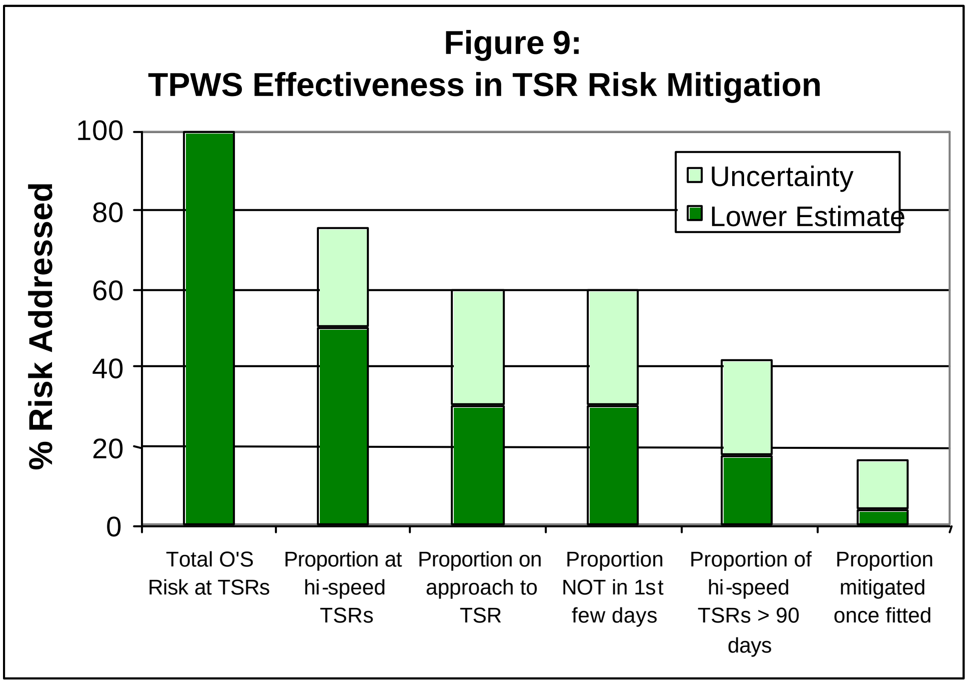
8(b) "Per Hi-Speed TSR" Parameters Used in Net Benefit Evaluation of Options

No. of "In-Year" TSR-yrs present on network, assumed long-term average	P	400	500		based on Railtrack prospectus; compatible with 459 from TSRs imposed in 2002
Proportion of TSR-yrs that are > 90 days	Q	50%			from Table 1, column 4
No. of "In-Year" TSR-yrs imposed in 2002 that were "hi speed"	R	39%			from Table 1, column 4
Risk per "all imposed in 2002" TSR-year	S	6.0E-06	2.3E-04	EF per TSR year	S = D / P
Risk per high-speed TSR	T	7.8E-06	4.4E-04	EF per hi-speed TSR year	T = (D * E) / (P * R)
TPWS addressable risk per high-speed TSR	V	4.7E-06	3.5E-04	EF per hi-speed TSR year	V = T * F * G
Average safety benefit per year of fitment of hi-speed TSR	W	9.3E-07	1.4E-04	EF per fitted hi-speed TSR year	W = V * K

3.79 The estimated effect of TPWS would be to mitigate somewhere between 4% and 17% of the overspeed derailment risk at TSRs.

3.80 On a "per TSR" basis, the effect of the above assessment is that the safety benefits, per "high speed" TSR fitted, would be about 9.3×10^{-7} to 1.4×10^{-4} EF per TSR year, once TPWS was fitted.

3.81 The effectiveness of TPWS in mitigating risk at TSRs, and the factors that limit it, are illustrated graphically in Figure 9.



4. Cost benefit analysis for fitment of TPWS at TSRs

4.1 The following sections consider the potential safety disbenefits associated with the time track workers have to spend at trackside fitting TPWS at TSRs and with Driver behaviour in response to fitment of TPWS at TSRs. It then summarises information on cost of fitment.

Track Worker Risk

4.2 We have previously raised with HSE the issue that track workers are obliged to spend significant time at the trackside to fit TPWS. In the case of fitment at TSRs they would then spend further time removing TPWS equipment when the TSR was lifted. During such periods these staff are at risk, and our initial estimates were that the risk to track workers of fitting TSRs might well outweigh the safety benefits of fitment, particularly for TSRs of relatively short durations beyond the 90 day requirement under the Regulations.

4.3 HSE indicated that they considered track worker risks a quite separate matter from train accident risks. The purpose of the Regulations was to mitigate the latter, and it was Network Rail's responsibility to minimise the former as far as practicable.

4.4 In order to provide an overall assessment of net benefits our earlier work on track worker risk fitting TPWS has been updated to reflect;

a) improved levels of track worker safety that should be attainable in future, given the initiatives taken by Network Rail in recent months to reduce risk at the trackside (most notably the introduction of the new RIMINI standard requiring a step improvement in the planning of work at the trackside), and

b) the effort we have devoted to developing a portable form of TPWS with its own power supply, that would be far quicker to install at the trackside and would be suitable for temporary use (for longer term use the conventional equipment would be preferred because of its longevity and lower maintenance requirements).

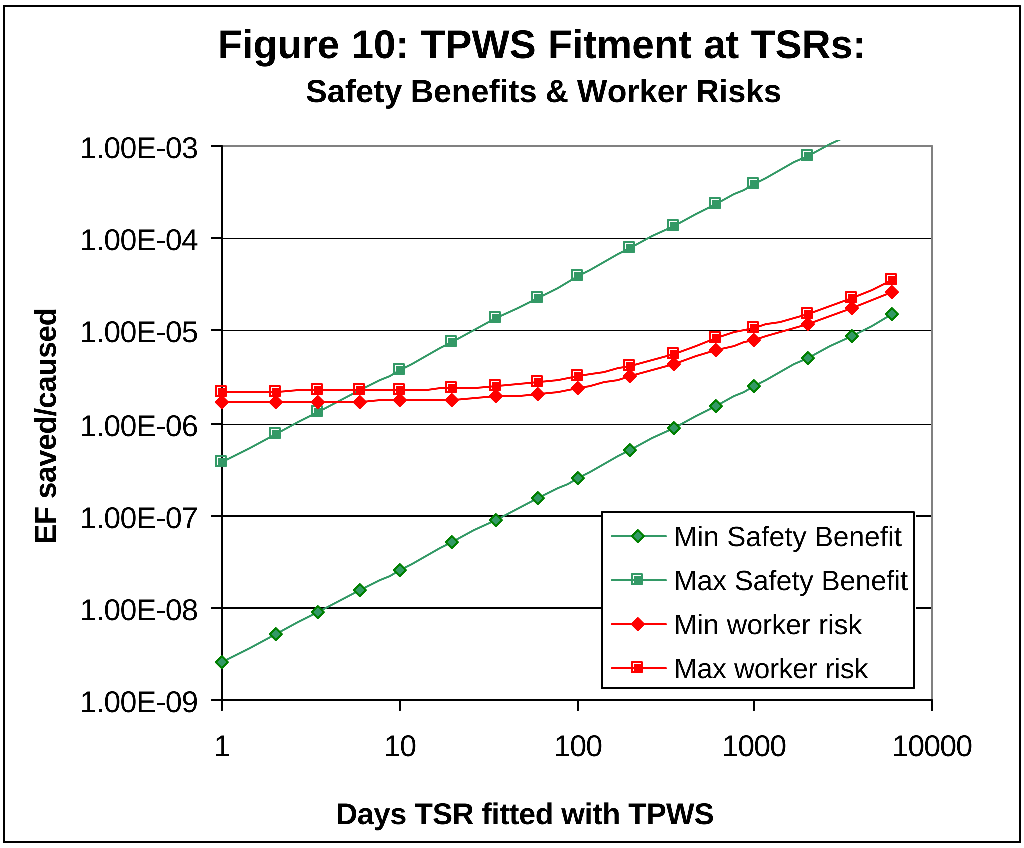
4.5 The assessment of the relevant average future risk per hour likely to be faced by track workers engaged in fitting and removing TPWS at TSRs is contained in Appendix 3. The conclusion is that the fatality risk is quite uncertain, in the range 2 to 5 x 10^{-8} fatalities per hour worked. The equivalent fatality risk, though, is dominated by more frequent minor injury incidents whose rate is less uncertain, and is estimated to lie in a relatively narrow band from 3 to 4 x 10^{-7} EF per hour worked.

4.6 Table 9 below summarises the risk levels and anticipated times at trackside involved in fitting either permanent or temporary TPWS equipment, and the corresponding "one off" risks of fitting & removing TPWS per TSR, and annualised risk of maintenance per TSR. The combined effects of improved track safety under RIMINI and of the major reduction in hours needed at trackside to install and remove the temporary TPWS equipment has been to make a substantial (4-5 fold) reduction in the estimated risk per TSR for track workers. This is regarded as being as low as could reasonably be hoped for in terms of unit track worker risk per TSR fitment.

Table 9: Worker Risk & Time at Trackside

Parameter	Min	Max	Notes
Fatality risk per person per hour	2.1E-08	5.1E-08	Appendix 2
EF risk per person per hour	2.8E-07	3.7E-07	
Average Man-hours to fit portable kit	6	N/A	
Average Man-hours to fit permanent kit	15		
Ave man-hrs/yr maintenance (portable kit)	10		
Ave man-hrs/yr maintenance (permanent kit)	5		
Risk (one off) to fit & uninstall portable kit	3.3E-06	4.4E-06	EF
Risk (one off) to fit & uninstall permanent kit	8.3E-06	1.1E-05	EF
Risk (annual) to maintain portable kit	2.8E-06	3.7E-06	EF/year
Risk (annual) to maintain permanent kit	1.4E-06	1.8E-06	EF/year

4.7 Figure 10 shows how the risk to track workers compares with the safety benefit in terms of overspeed derailment risk reduction, as a function of the length of time for which TPWS is fitted at a TSR, based on the unit benefits and risks in Tables 8 and 9.



4.8 For short durations of fitment the track worker risk, measured in equivalent fatalities, certainly outweighs the derailment risk reduction. Because the uncertainty in the safety benefit is so wide, and TPWS equipment requires ongoing maintenance work at the trackside, there is no timescale beyond which the safety benefit of fitment certainly outweighs the worker risk. It is concluded that it is entirely possible, but by no means certain, that the risk to track staff engaged in fitting TPWS will outweigh the benefits gained in train accident risk reduction.

Driver Response to TPWS at TSRs

4.9 In earlier reports on the use of TPWS at PSRs with approach control signalling a very important practical safety issue surrounding the application of TPWS for overspeed risk mitigation generally was highlighted. This issue is at least as important, if not more so, for TSRs than for PSRs.

4.10 The issue is that the entire benefits of TPWS (including the much larger SPAD risk reduction benefits as well as overspeed risk reduction benefits) depend on Driver confidence in the TPWS system. There have been 9 incidents in which a Driver whose train was correctly stopped by TPWS thought the system had operated incorrectly, reset the TPWS equipment, and carried on into danger.

4.11 The key questions this raises in connection with TSRs are:

- What will using TPWS at TSRs do to Driver confidence in TPWS generally?
- How will this affect their behaviour at TSRs? and
- How will this affect their behaviour in general when TPWS operates?

4.12 The answer to the first question is that using TPWS at speed restrictions generally, but at TSRs in particular, will almost certainly increase Driver perceptions that TPWS is prone to intervene in situations they regard as well within the safe "envelope" of normal driving. This is because there is a very wide range of Driver approaches to speed restrictions, in different trains, in different track circumstances, and varying from Driver to Driver. Our experience to date in the use of TPWS at PSRs has been that when certain PSRs are first fitted, there is a "rash" of TPWS interventions, until Drivers learn how they need to approach the speed restriction to avoid tripping the TPWS equipment. With TSRs, the likelihood is that the learning period for such approaches will overlap with the period for which the TSR is fitted, raising a general perception that "TPWS is likely to intervene inappropriately at speed restrictions, particularly at TSRs". Also, TSRs will by definition keep appearing in different places year in year out, thus the "rash" of interventions when a TSR is first applied will be an ongoing issue. We suggest that this will cause a significant degree of resentment towards TPWS among Drivers, and a reduced general level of confidence in the TPWS system generally – in particular, an increased general perception that TPWS is prone to intervene inappropriately.

4.13 One possible response to any such perceptions might be for Drivers to alter their behaviour at TSRs. They will quickly learn where the TPWS loops are, and might respond to any sense of "resistance" towards TPWS by accelerating after the loops had been passed, thus eroding the (already small) effectiveness of TPWS in derailment mitigation.

4.14 Much more importantly, there is a concern that any increase in general perceptions that TPWS is prone to inappropriate interventions could lead to an increased propensity among Drivers to re-set the system and drive on, when it has correctly intervened to mitigate a SPAD. This possibility was considered in the earlier report on ACS-PSRs, and deduced that the risk associated with a single such incident was of order 0.02 to 0.1 EF. That is, the net effect of one such incident would significantly outweigh (at least by a factor of two, and possibly by a factor of several thousands) the entire benefits of fitting a year's worth of TSRs.

4.15 It is far from clear whether train Drivers will understand why some TSRs have protection and others do not. What effect does this have on their confidence in the system unless they can clearly understand the rules being used? There is also a learnt knowledge issue in that most SPADs are self indicating to the Signaller so the Driver is "bound" to report them. Most overspeed incidents will not be observable and will rely on other means of detection (e.g. train data recorders).

4.16 During the development of the application rules for TPWS at PSRs it became evident that defensive driving techniques do not generally apply to PSRs and full service braking was expected or condoned by many train operators. Adopting a full service braking approach to the design criteria was likely to lead to little headroom between what was considered to be a legitimate approach and what was considered to be a train not in control, whilst reducing potential train protection. In practice this has been borne out as PSRs continue to be the source of many TPWS interventions, many alleged by TOCs to be inappropriate. By comparison with interventions at red signals (where defensive driving techniques are universally employed) there have been 618 interventions at PSRs in 16 months compared with 283 interventions at signal OSSs in over 2 years, a rate of approximately 4:1.

4.17 The matter of Driver confidence has been raised by individual train operators and ATOC Operations Council during the consultation exercise that was undertaken with them. They stated that the introduction of TPWS at TSRs would further reduce this confidence in TPWS as a train protection system.

Costs of Fitment

4.18 Finally, in any overall evaluation of the net benefits and disbenefits of applying a new safety system, the costs need to be factored in on the "disbenefits" side. Table 10 shows our latest estimates of direct costs of fitting TPWS equipment of various sorts.

Table 10: Costs & Timescales of TPWS Fitment

Item	Value *	Notes
Average fixed installation at PSR	£15,000	Based on PSR experience to date
Estimated cost to use standard fixed installation hardware for temporary TSR installations	£11,500	Assumes significantly reduced design work for temporary installations
Estimated cost using self-powered version of fixed installation hardware	£9,100	Reduces power supply costs; otherwise similar installation effort
Estimated cost using new portable (reusable) equipment	£8,500	Has particular benefit of reducing hours at trackside for fitment

** £ values are for direct equipment & installation cost, excluding maintenance, overheads etc*

4.19 These costs are very much lower bounds, in that they do not include maintenance or any element of overhead cost recovery or profit by either Network Rail or its' contractors. The top figure, for fixed installation at PSRs, is becoming relatively well established as significant numbers of PSRs have now been fitted. The bottom two costs are both more aspirational, based on equipment still under development, and there cannot be certainty that temporary equipment could be deployed for this cost.

4.20 The cost-benefit assessment in the following section has used the lowest of the unit costs in Table 10 above, i.e. has assumed that the temporary portable equipment will be successfully developed and deployed for the cost indicated in the Table.

Net Benefits of TPWS Fitment at TSRs

4.21 The sample of TSRs imposed in calendar year 2002 and described earlier has been used along with the TSR risk, TPWS effectiveness, worker risk increase and cost estimates to estimate the overall safety benefits, disbenefits and costs associated with using TPWS at TSRs.

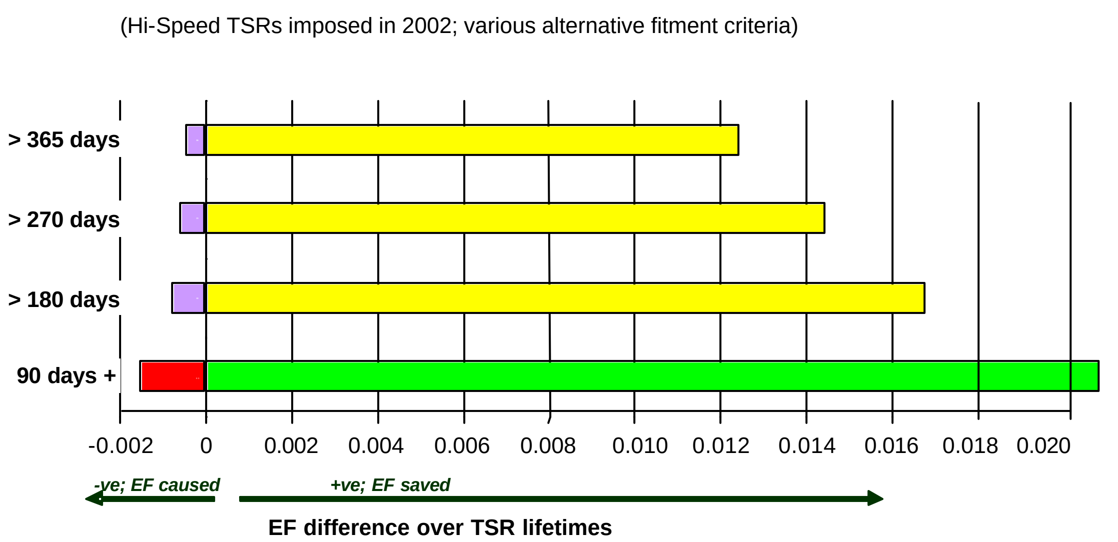
4.22 The potential safety risk of adverse Driver responses to TPWS at TSRs has not been factored directly into this assessment, but this does not mean it is unimportant. On the contrary, given the results of the assessment, this risk is regarded as a compelling safety and practical reason for great caution in the application of TPWS at TSRs.

4.23 Tables 11 and 12 show the numbers of TSRs involved, the TSR-years involved, the upper and lower estimates of derailment risk reduction benefit and of worker risk increase, and the costs of fitment based on the sample of 251 TSRs imposed in 2002 (Table 11) and for the long-term "Legacy" TSRs in place at the end of 2002 (Table 12) that would have come within the scope of the Regulations. The table also illustrates the effect of using alternative fitment criteria, i.e. lengthening the duration of a TSR before which fitment became required under the Regulations. Note - Table 11 takes the long-term average risk per 'high speed TSR year' and applies it to the actual numbers of TSR years in 2002. Hence estimates for 2002 in Table 11 are different from the "long term rough average" estimates in Table 8 for network-wide derailment safety benefits associated with TPWS at TSRs.

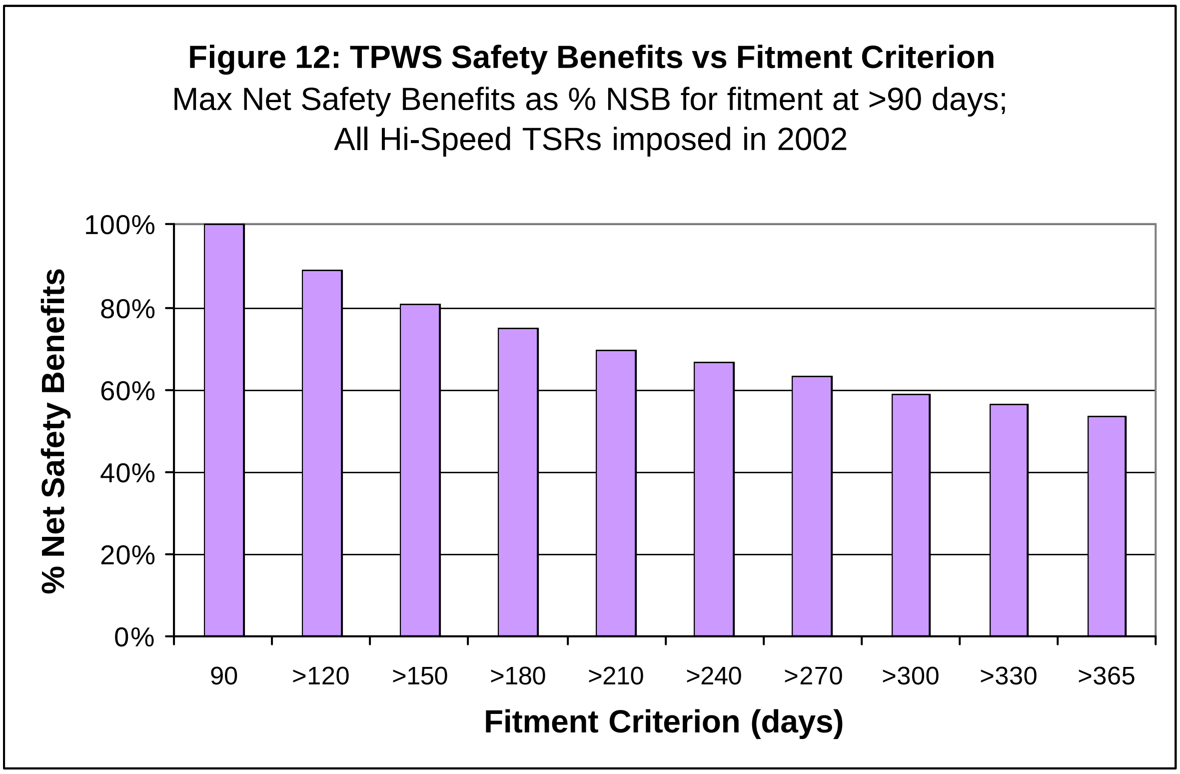
4.24 At the right of each table there is an indication of the implied value of preventing an equivalent fatality, which is simply the ratio of the cost of fitment to the safety benefits of fitment (note that in each case the true upper value is infinite or negative, as in each case there is no certainty whether the safety benefits will outweigh the disbenefits – to avoid the problem of dealing with infinite or negative numbers the estimate of the upper value per EF avoided in each case disregards the worker risk, and considers the lower estimate of derailment risk reduction as the relevant safety benefit of fitment).

4.25 Figure 11 shows the net safety benefit (which could be either +ve or -ve) of fitting the sample of TSRs imposed in 2002, as a function of number of days chosen as the lower criterion for fitment. Figure 14 shows the counterpart for the small set of "legacy" TSRs that would have required fitment as at 1 January 2003.

Figure 11: Net Safety Benefits of TPWS Fitment



4.26 Figure 12 shows the maximum safety benefits as a percentage of those achieved by fitting all TSRs of duration 90+ days, for longer minimum durations of fitment. Figure 13 shows the range of values of preventing an equivalent fatality implied by the assessment for each minimum duration of fitment.



4.27 The lower and upper estimates of total derailment risk reduction benefit from TPWS fitment in accordance with the Regulations, based on the sample of TSRs imposed in 2002, is between 1.7×10^{-4} and 2.6×10^{-2} EF per year (Table 11 column 4 and 5, first row).

4.28 Figure 13 illustrates the improvement in the implied VPF (i.e. the better benefit/cost ratio) obtainable by extending the time beyond which TSRs are required to be fitted. For fitment at greater than 90 days (as per the Regulations), the implied VPF is somewhere in the range £87 million to £12.3 billion. Note that although the uncertainty is large, there can be a high degree of confidence that the implied VPF is no less than £87 million, whereas it is possible that the overall effect is zero or negative (thus the implied VPF infinite or negative).

4.29 Figure 14 shows that the overall benefit of fitting the long-term "legacy" TSRs is modest in comparison with fitting the newer TSRs illustrated in Figure 11. This is because the number of "legacy" TSRs that fall within the scope of the Regulations is small (most high speed routes would, understandably, be a high priority for works to enable TSRs to be removed). What benefit there is concentrated in the 1-2 year old TSRs, so there is not some long one-off "tail" of very old TSRs that it would be particularly beneficial to fit with TPWS.

Table 11: Net Impacts of Fitment of Hi-Speed TSRs with TPWS

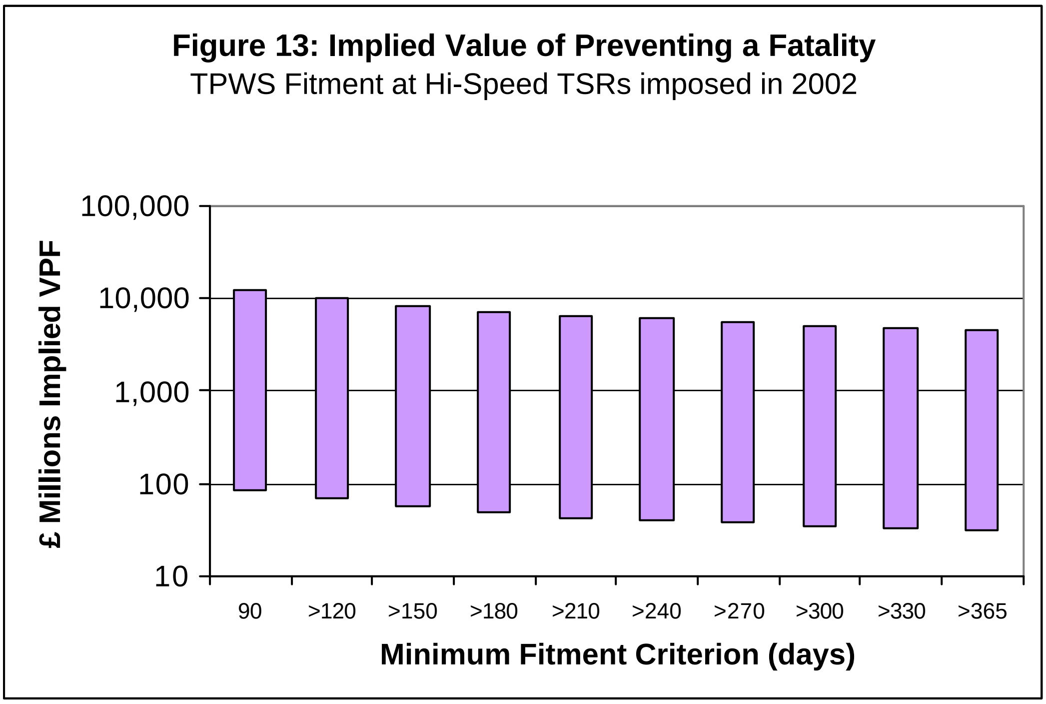
All Safety Benefit and Risk units are absolute EF gained/lost through one year's fitments (based on 2002 TSRs)

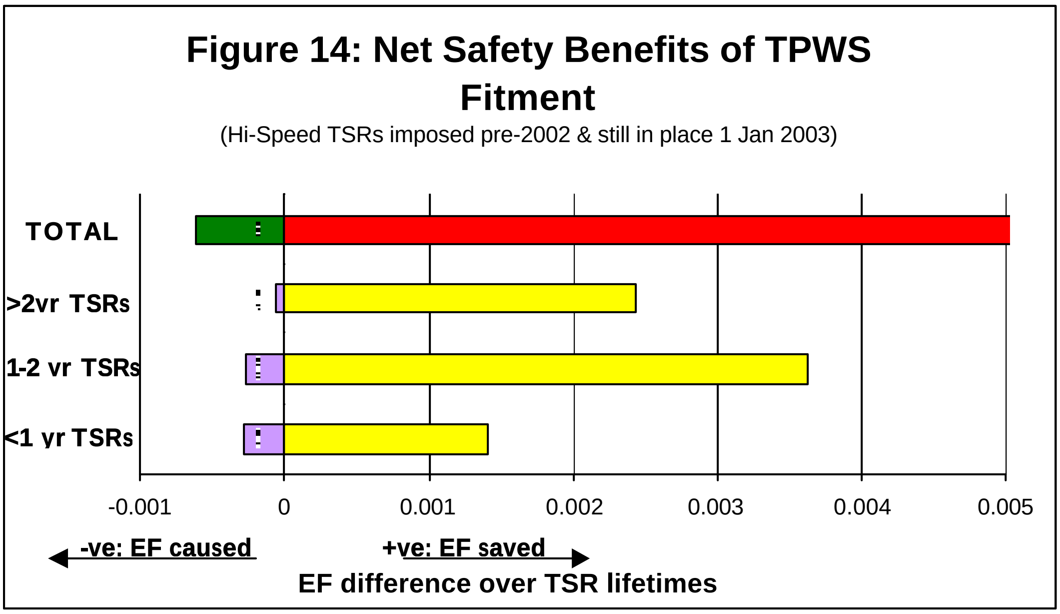
Days before TPWS installed	No fitted per year	Equiv TSR years	Minimum derailment safety benefit	Maximum derailment safety benefit	Minimum worker risk	Maximum worker risk	Minimum net safety benefit	Maximum net safety benefit	Maximum as % value	Cost of fitment £million	Implied minimum VPF £million	Implied maximum VPF £million
>90	251	186	1.7E-04	2.6E-02	1.3E-03	1.8E-03	-1.6E-03	2.5E-02	100.0	2.13	87	12,329
>120	176	164	1.5E-04	2.3E-02	1.0E-03	1.4E-03	-1.2E-03	2.2E-02	89.1	1.50	68	9,769
>150	131	148	1.4E-04	2.1E-02	8.4E-04	1.1E-03	-9.8E-04	2.0E-02	80.7	1.11	56	8,069
>180	106	137	1.3E-04	1.9E-02	7.3E-04	9.6E-04	-8.4E-04	1.8E-02	74.8	0.90	49	7,063
>210	87	127	1.2E-04	1.8E-02	6.4E-04	8.4E-04	-7.3E-04	1.7E-02	69.4	0.74	43	6,262
>240	79	122	1.1E-04	1.7E-02	6.0E-04	7.9E-04	-6.8E-04	1.6E-02	66.8	0.67	41	5,915
>270	69	115	1.1E-04	1.6E-02	5.5E-04	7.2E-04	-6.1E-04	1.6E-02	63.0	0.59	38	5,478
>300	59	107	1.0E-05	1.5E-02	4.9E-04	6.5E-04	-5.5E-04	1.4E-02	58.8	0.50	35	5,025
>330	54	103	9.6E-05	1.4E-02	4.6E-04	6.1E-04	-5.2E-04	1.4E-02	56.5	0.46	33	4,788
>360	48	97	9.1E-05	1.4E-02	4.3E-04	5.6E-04	-4.7E-04	1.3E-02	53.5	0.41	31	4,504

* NOTE - Table 11 takes the long-term average risk per high speed TSR year and applies it to the actual numbers of TSR years in 2002 (which is different from the long-term average no.). Hence estimates for 2002 in Table 11 are different from the "long term rough average" estimates in Table 8 for network-wide derailment safety benefits associated with TPWS at TSRs

Table 12: Net Benefits of TPWS Fitment at "Long Term" Hi-Speed

Future TSR duration	No. TSRs in sample set	Min Safety Benefit	Max Safety Benefit	Min Worker Risk	Max Worker Risk	Min NET Safety Benefit	Max Net Safety Benefit	Max NSB per TSR fitted	Total cost of fitment £	Implied VPF (least) £ millions	Implied VPF (most) £ millions
< 1 yr TSRs	25	2.52E-06	8.82E-04	2.19E-04	2.90E-04	-2.88E-04	6.62E-04	2.65E-05	375000	321	148,829
1-2 yr TSRs	22	7.01E-06	2.46E-03	2.17E-04	2.87E-04	-2.80E-04	2.24E-03	1.02E-04	330000	147	47,044
> 2 yr TSRs	4	4.84E-06	1.70E-03	5.70E-05	7.54E-05	-7.06E-05	1.64E-03	4.10E-04	60000	37	12,387
TOTAL	**51**	**1.44E-05**	**5.03E-03**	**4.93E-04**	**6.52E-04**	**-6.38E-04**	**4.54E-03**	**8.90E-05**	**765000**	**169**	**53,205**





4.30 The overall conclusions drawn from these tables and figures are that:

- the maximum postulated safety benefits in terms of overspeed derailment risk reduction are very small (just over 0.026 EF per year, Table 11).
- there is no certainty that the safety benefits to train occupants would outweigh the risks of fitment to track workers.

- the safety benefits of fitment fall off relatively gradually as the minimum duration of fitment is increased (Figure 12).
- the implied value of preventing an equivalent fatality of fitment in accordance with the Regulations lies somewhere within a very broad range from about £87 million to about £12.3 billion.
- this implied VPF can be improved slightly, but not sufficiently to meet the current industry criteria, by extending the minimum TSR duration for which fitment is required; fitment of TSRs of duration greater than a year would bring the range down to about £31 million to £4.5 billion.
- the extra benefits of fitting the long term "legacy" TSRs (sampled as those that had existed for more than a year at the start of 2003) are modest because the number requiring fitment is small.

4.31 The general picture BEFORE consideration of the potential safety disbenefits of adverse impacts of using TPWS at TSRs on Driver behaviour is that the benefits of using TPWS at TSRs are small and uncertain (within a range from small to very small – there is no possibility that they are in fact considerable). While the overall costs are not large in terms of major railway safety initiatives (up to about £2 million per year) they appear disproportionate to the potential safety benefits, even if the potential safety disbenefits are ignored. Similarly, concerns exist regarding the interfacing of temporary equipment to safety critical signalling circuits.

4.32 There is a particular concern throughout this assessment that the debate over the use of TPWS at TSRs should not become bogged down in arguments about costs and benefits. There is a much more important issue that weighs strongly against simply applying the Regulations and fitting TPWS at TSRs. This is the issue of what Drivers see as unwarranted interventions by TPWS eroding their confidence that TPWS can be relied on to intervene when it should, and not to intervene when it should not.

4.33 Even a very small increase in perceptions among Drivers that TPWS interventions are often not warranted could lead to an erosion of the overall effectiveness of TPWS (including the very much larger benefits of SPAD risk reduction) of several orders of magnitude greater than the entire potential benefits of using TPWS at speed restrictions. There is every reason to suppose that the impact of using TPWS at TSRs on Driver perceptions of this sort will be considerable, though it is impossible to quantify. This view is shared by the train operators that responded to the consultation exercise undertaken prior to the submission of this Exemption application.

5. Practical Issues in using TPWS at TSRs

5.1 TSRs are implemented for various durations ranging from a matter of a few days to several years. Although this exemption seeks not to install TPWS at TSRs, Network Rail has been undertaking the design of suitable equipment for such installations if so required by HMRI.

Constraints to TPWS protection at TSRs

5.2 Currently, two trackside TPWS equipment solutions would be available for addressing overspeed derailment risk. These are both Overspeed Sensor Systems (OSS), one being connected to a local signalling power supply the other having a self-contained power source (the Self-Powered OSS or SPOSS). Both of these existing solutions are designed to be installed long term (25 year design life) and are hence not portable and would require a reasonable amount of design and infrastructure work to install and remove them. Thus they are not considered to be appropriate for short duration TSR applications (in essence this is an issue of reducing track worker risk to ALARP recognising limited safety benefit to train occupants), but may be appropriate for longer term TSR applications.

5.3 Thales Communications UK (TCUK) have conducted a feasibility study into truly portable TPWS equipment. They have developed a concept of lightweight equipment fixed to the track using Vortok 'quick release' rail fixings, avoiding the need for drilling sleepers or removing rail fixings. Two options are suggested, one a self-powered OSS arrangement and the second a Train Stop System (TSS). A design, development and product/type approval process has commenced and will last until June 2004.

Technical issues

5.4 Besides offering little in the way of overall protection at speed restrictions, TPWS introduces significant issues of practicality:

Freight Train Timer Issue

5.5 The Set Speed of TPWS OSSs are affected by the different on-board TPWS timer setting on freight trains. This is documented in RMD1/TPWS/REP/500 and is factored into the spreadsheet used for calculating OSS positions at PSRs. Unless this issue is taken into account when designing an OSS for a TSR, then it could lead to erroneous brake interventions on freight trains. The result is that some regulated TSRs may not be able to be protected by TPWS due to the reasons outlined in the referenced report already submitted to HMRI and subject to a separate Exemption.

5.6 The concept of portable TSR equipment for short duration (i.e. <1 year) TSRs includes an option that would overcome the freight train timer issue by moving the timing function from the train to the trackside (TSS option). This is the favoured option as it also creates a smaller overall package, increasing the portability of the equipment. However, significant risks exist in finding a suitable train speed detection system for this option and it may not turn out to be practical.

Differential Speed Restrictions

5.7 Certain TSRs have a different speed limit for certain classes of train, e.g. a lower speed may exist for freight trains. Trackside TPWS equipment is unable to determine the difference between approaching train types and hence cannot determine whether, or at what speed, it should intervene on an approaching train. For this reason, TPWS application at speed restrictions has been accepted on the basis that TPWS will only be capable of being set to protect the highest approaching train speed otherwise all trains will be either forced to slow down to the lowest speed or risk a brake intervention, or protection for higher speed trains will be significantly compromised. Therefore, TPWS at TSRs would have to follow suit and be applied only to the higher of differential speed restrictions. In certain cases TPWS would not be provided:

- where the higher speed would not in its own right justify fitment of TPWS, i.e. if the reduction in speed is less than one third of the approach speed.
- where the TSR only applies to freight trains and not passenger trains.

Complex Approaches

5.8 A complex approach is defined as a location requiring TPWS protection that can be approached from more than one direction (convergence), or the equipment can be passed over by trains going in the same direction but are not approaching the location being protected (divergence).

5.9 At converging approaches to a TSR, trains can approach from more than one route and hence more than one set of TPWS equipment would be required. If one or more of the separate approaches also has another route besides that which the TSR is on, then that TPWS equipment may have to be switched on and off depending on which route is set (it is then also a diverging route).

5.10 For diverging approaches, the TPWS equipment would need to be switched on and off depending on which route is set. For example, TPWS protection may be required for a TSR that only applies to one route and will need switching off for the route to which the TPWS equipment does not apply. This would typically be the case where the TSR was just the other side of a diverging set of points. Figure 15 shows an example of a complex approach.

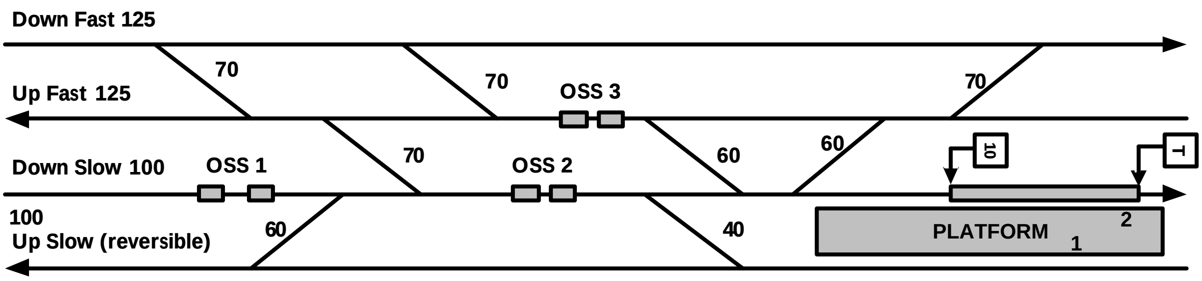


Figure 15 – Example Complex Approach

5.11 In the above example OSS1 is protecting the Down Slow approach to the TSR (100 to 10 mph); OSS2 is protecting both the Down Fast Route 1 approach to the TSR (125/70/70 to 10mph) and the Up Slow (reversible) approach to the TSR (100/60 to 10 mph); OSS3 is protecting the Down Fast Route 2 approach to the TSR (125/70/60 to 10mph). The following conditioning is required:

- OSS1 and OSS2 off for trains routed from the Down Slow to terminate in Platform 1
- OSS2 off for trains routed from the Down Fast to terminate in Platform 1

- OSS2 off for trains routed from the Up Slow (reversible) to the Down Fast
- OSS1 and OSS2 off for trains routed from the Down Slow to the Down Fast

5.12 As can be seen from the above example, managing complex approaches has significant complexities:

- multiple sets of TPWS equipment would be required for one TSR.
- multiple sets of equipment would need to be conditioned by the signalling system.
- neither the existing SPOSS or the concept portable equipment are capable of being switched by signalling equipment.
- the solution would have to use standard 110V ac OSS equipment, interfaced to the signalling system for route selec tion as well as power for a relatively short period of time.
- if the complex approach is in an SSI signalled area it would be necessary to either employ an SSI data change or install points relays, neither of which is considered to be reasonably practicable for a temporary installation of TPWS.

Current TSR design

5.13 The current situation is that all TSRs require an element of 'design'. A suite of standard look-up tables provide the required distance for the Warning Board from the start of the TSR (based on Maximum Permissible Speed on approach and permissible speed of the TSR). The standard distance has to be adjusted according to the gradient on approach. The design of the existing TSR protection does not need to account for the achievable performance of approaching trains.

5.14 This is entirely appropriate as the functionality of the temporary AWS magnet and the Warning Board are not themselves speed dependent, only the distance between the Warning and Commencement Boards is speed dependent (available braking distance). Thus, if the train actually approaches slower than the maximum permitted speed, the Warning Board will be further in rear than strictly necessary, but this errs on the side of safety.

5.15 The second element of 'design' involves determining whether there is any existing AWS equipment which may need to be temporarily disconnected to be used for the TSR AWS magnet function, and whether the temporary AWS magnet would fall within an 'AWS gap' area in which case it must not be provided. Railway Group Standards for signalling design permit such design of a temporary nature to avoid updating the master records provided the temporary design is available and the maintainer has been briefed on the nature of the temporary work. Thus there is an element of signal design required although this is fairly limited.

TSR design with TPWS

5.16 For the purposes of TPWS design at TSRs, the design can be considered to fall into one of two categories: simple or complex. Regardless of which category they fall into the amount of design activity surrounding the application of a TSR will increase compared with the current situation, in some cases significantly, extending the requirement from signalling designers.

5.17 The concept of a simple TSR is where there would be no need to interface the TSR equipment to the signalling system or the interface is limited to sourcing a power supply.

5.18 The concept of a complex TSR is where there would be a need to interface the TPWS equipment to the signalling system to condition the equipment dependent on route set, as outlined in sections 5.8 to 5.12 above.

All TPWS installations at TSRs

5.19 The relatively simple approach to designing existing TSR protection, described in Sections 5.13 to 5.15, cannot be taken with TPWS equipment. This is because the functionality of the TPWS equipment itself is speed dependent. Unless factors which affect the speed of approach of trains to the TSR are considered, the Set Speed of the TPWS equipment might be higher than any train can actually achieve, thus negating any protection offered. Therefore, to apply TPWS at a TSR would require a calculation to be made of the Attainable Speed (as is currently the case for TPWS at PSRs). This would require:

- determination of whether a PSR in rear of the TSR will affect Attainable Speed (this may be several miles in rear).
- obtaining gradient data over a much extended distance compared with today's situation as this will also affect Attainable Speed.

5.20 Calculation of Attainable Speed would also be required to identify whether trains could actually approach the TSR at 60mph or above or if the speed at entry into the TSR is less than the permitted overspeed of the TSR (i.e. derailment risk is minimal).

5.21 The allowable overspeed margin may well be different for various classes of Condition of Track TSR, hence requiring a design bespoke to the type of hazard being protected.

5.22 A further complication would exist where there is another TSR in rear of the TSR being fitted with TPWS. In this case the assumed approach speed of trains would again be incorrect and the TPWS equipment may not provide any protection until the TSR in rear is itself removed. If the TSR in rear is taken into account then the TPWS fitted TSR would have to be re-calculated when the TSR in rear was removed as then trains would be approaching faster than the design calculation assumed and insufficient braking distance could be available. As the TPWS equipment is only on for a short period of time then it would seem inappropriate not to consider any TSRs in rear yet this would double the design and installation requirements if the equipment had to be repositioned part way through its (short) life. Taken to extremes, the TSR in rear of the TSR being protected may be removed a matter of days before the TSR being protected with TPWS is itself lifted rendering the TPWS fitment entirely superfluous.

5.23 These calculations would be required to determine the Nominal Design position of the TPWS equipment prior to conducting a site visit to survey the proposed location of the TPWS equipment. The site survey would be required to:

- verify the design data used to calculate equipment position.

- confirm that the TPWS equipment can be fitted at Nominal Design position (identify any potential obstructions or other infrastructure that may offer constraints on equipment positioning) or select a suitable alternative.
- determine the TPWS equipment requirements (loop mounting arrangements, rail type for treadle bracket etc.).

This is all additional work not currently required in the train protection system in place today at TSRs.

TPWS installation at simple TSRs

5.24 For a simple TSR, the preferred option would be to utilise portable TPWS equipment where the planned duration does not exceed 12 months, and fixed equipment where the TSR is planned to be of extended duration (normally greater than 12 months).

5.25 For the new portable TPWS equipment, the only additional design activity would be to determine the specific equipment set up requirement, e.g. train detector positioning with respect to loops.

5.26 Where fixed equipment is used, the only addition design activity will be to be source a 110V ac signalling power supply. For this it will be necessary to undertake correlation of the signalling interface but this should be limited to the fuse/terminals proposed to source the power supply.

5.27 A temporary design would need to be produced and managed to ensure any maintenance or new works were controlled.

5.28 With either solution, the location of the equipment would need to be published to the controlling Signal box in order to deal with any reported TPWS interventions.

TPWS installation at complex TSRs

5.29 Where TPWS equipment was to be applied in a complex approach, the level of signalling design would be significant. In some cases the time taken to undertake the correlation, design, checking, installation and testing would be disproportionate to the duration of the TSR itself. Access to SSI data change resources would be a severe limitation if the only option were to switch the equipment through TFM outputs in SSI controlled areas. In many cases it is estimated that the TSR would be lifted before the data change could be applied.

Installation requirements

5.30 Prior to the mid 1990s, TSRs were implemented by a combination of Track staff to undertake installations of warning boards and temporary AWS magnet, and Signal Technicians to connect power to the TSR boards which were illuminated by electric lamps.

5.31 Since the general move to reflectorised lineside boards, with a few exceptions, the complete installation process is undertaken by Track staff only. Anecdotally, the reliability of implementing the TSR when required has improved as a result of dispensing with the need for co-ordinated attendance of Track staff and Signal Technicians, the latter often being diverted to more pressing requirements such as signalling failures. There is no requirement for testing of the 'standard' TSR installation when set up by Track staff.

5.32 The exceptions to implementation by Track staff alone are primarily where an illuminated lineside sign is required, e.g. if the TSR warning board is in a tunnel, or where there is a need to disconnect existing signal AWS equipment.

5.33 To apply TPWS at TSRs it would again require a combination of Track staff, Signal Technicians and signal testing resource would be required.

Risk Mitigation Pending TPWS Being Installed

5.34 The current requirement of the Regulations is to implement train protection if the TSR is to be in place for longer than 3 months. If the planning process commences early enough (e.g. commensurate with Rule of the Route requirements) then this should be achievable even if significant signalling design were to be required.

5.35 However, where the TSR is originally planned to be in place for less than 3 months (and hence TPWS is not initially provided) and its duration is extended after implementation to beyond 3 months due to, for example, unexpected additional work or loss of a possession, then consideration would need to be given to what risk mitigation measures would be required as an interim to implementing TPWS. The requirement in the Regulations is effectively saying that the risk is not acceptable after 3 months of duration, hence would it be necessary to 'Stop and Caution' trains on the approach to a TSR after 3 months until TPWS is installed? If so then this would have significant performance implications.

Removal of Equipment

5.36 The removal of the TPWS equipment would have to be co-ordinated with the lifting of the TSR otherwise trains would still be subject to a speed check despite the removal of the TSR itself. With portable equipment, this should not present too much of a difficulty. However, the use of semi-fixed equipment at complex approaches has significant risk that signalling resource may not be available to remove the TPWS equipment and restore the infrastructure back to original concurrent with ability to lift the restriction. Therefore, the TSR would be extended beyond the required duration further affecting train performance. The removal of the equipment would also need to tie in with a publication of the WON.

Maintenance of current TSR equipment

5.37 Maintenance of current TSR equipment is limited to ensuring the lineside signs are still in position and are clean. There is no routine test of the temporary AWS magnet once in service (the AWS magnet is tested at the maintenance depot before use).

5.38 For long term TSRs semi-fixed equipment would be subject to the existing maintenance requirements. This consists of a 3 monthly inspection and annual test regime. Where used, a SPOSS would also be subject to an annual battery change.

5.39 The portable TSR equipment would be designed to be 'maintenance free' during the 12 months in-service period. Battery changing would be a minimum of 12 monthly such that no site visits would be required to change batteries unless the equipment were to remain in service for longer than 12 months. The equipment would be tested before going to site rather like AWS magnets.

5.40 However, the portable equipment would be significantly more complex than an AWS magnet and it is unlikely that the equipment could be fitted and left for up to 12 months without regular inspection to ensure it was working. The inspection requirements for the portable equipment would largely be shaped by the staff who would be required to carry out the maintenance. The aim would be to have a visible indication of functionality but access to the track would still be needed to confirm functionality, provisionally on a 3 monthly basis (although this would be subject to an ALARP assessment).

Use of Resources

5.41 The resources needed to survey, design, install, test/commission, maintain and recover TPWS equipment at TSRs will be signalling design and maintenance technicians. There is a general scarcity of these resources to manage maintenance activities on the operational railway. This would place an ever greater demand on these scarce resources. If complex TSRs were to be fitted then signalling design engineers would be required that would affect resource availability for general signal renewals works, and other works which requires a large amount of skilled signalling resource, such as level crossings improvements.

6. Consultation with Train Operators

6.1 During August 2003 Network Rail consulted with industry parties about the fitment of TPWS at TSRs. The parties consulted were the train operating company managing directors, members of the TPWS System Authority, SRA, ORR and RSSB. The consultation papers were copied to HMRI for their information. The documents provided to those parties were:

- a covering letter explaining Network Rails intention to seek an Exemption for the fitment of TPWS, and a summary of the issues associated with TPWS fitment at TSRs. The letter asked for the views of the recipients about the fitment of TPWS to TSRs and, in particular, asked whether fitment should happen after a TSR had been in place for 1 year or whether no TSRs should be fitted, or whether the recipient had any other suggestion for TSR fitment;
- a report prepared for Network Rail by Tony Taig of TTAC Ltd entitled 'The Application and Effectiveness of TPWS at Temporary Speed Restrictions (TSRs)';
- a report by Network Rail entitled 'The Applications of TPWS at TSRs'.

6.2 Network Rail also met with the Association of Train Operating Companies Operations Council on 11 August. Network Rail tabled the letter and 2 reports that had been circulated within the industry, and these were discussed.

6.3 The content of the 2 reports have been combined to form the basis of this exemption application.

6.4 The responses that Network Rail has received as a result of the consultation exercise can be summarised as follows:

- The Minutes of the ATOC Operations Council meeting states that it was unanimously agreed that TPWS should not be fitted to any TSRs;

- 6 passenger train operating companies responded. All expressed concern that the fitment of TPWS would reduce Driver confidence in the system as a whole. Of the 6, 4 stated that no TSRs should be fitted with TPWS and the other 2 stated that only TSRs in place for more than 1 year should be fitted with TPWS.

6.5 Should HMRI wish to have sight of the responses received by Network Rail during their consideration of this application, the responses will be made available to HMRI for those operators that indicated their willingness for the response to be shared with HMRI.

7. Conclusions

7.1 Based on our analysis of the numbers of TSRs imposed on the network during 2002 and up to the present day the Regulations would require around 250 fitments of TPWS to be made annually at TSRs, with around 320 fitments existing during any one 12 month period.

7.2 Network Rail has given a commitment to reduce the numbers of TSRs on the network and so the number of fitments that would be required should reduce over time.

7.3 The safety risk of overspeed derailments at TSRs is uncertain, lying in the range 0.003 to 0.09 EF per year (1 fatal accident every 60 to 2000 years).

7.4 The proportion of this addressable by TPWS is limited (in the range 5 to 30%), because significant proportions of the risk:

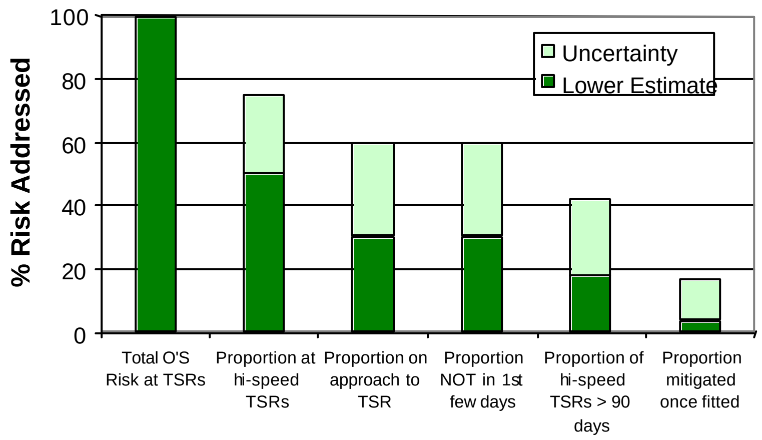
a) are at lower speed TSRs not covered by the Regulations (25-50%).

b) entail overspeeding within, not on the approach to, TSRs (20-40%).

c) entail TSRs of less than 90 days not covered by the Regulations (30-40%).

7.5 The effectiveness of TPWS in mitigating that portion of the risk it can address is limited to 20-40% because of the inherent limitations of using the "one shot" overspeed protection loops on a mixed traffic system. The overall effectiveness of TPWS in mitigating overspeed derailment risk at TSRs is thus very modest, in the range 4 to 17 % before any limitations associated with the time required to fit TPWS are taken into consideration (see Figure 9, reproduced below).

Figure 9:
TPWS Effectiveness in TSR Risk Mitigation



7.6 The overall effect of fitment of TPWS in accordance with the Regulations would be to produce a net safety benefit of at best about 0.025 EF per year, and at worst a **net safety disbenefit** of about 0.0016 EF per year, BEFORE any effects on Driver confidence in TPWS are considered.

7.7 The uncertainty in these estimates is large, but there can be very high confidence that the costs and disbenefits of using TPWS at TSRs are large in relation to the benefits.

7.8 The potential effects of using TPWS at TSRs on Driver perceptions that TPWS may intervene when it should not are considerable. It is predicted that TPWS at TSRs will introduce disproportionately high numbers of interventions due to the lack of route knowledge for what is a temporary feature that can appear at any particular location. Train operators and ATOC Operations Council have confirmed to Network Rail that they also have this concern.

7.9 The potential impact on Driver perceptions of using TPWS at TSRs outweighs all the other considerations of safety benefits, risk and costs addressed in this report. It causes grave concern over the whole concept of using TPWS at speed restrictions, other than in very special circumstances. This is because it has the potential significantly to erode the ENTIRE benefits of the whole TPWS system (including the very much greater benefits of using TPWS for SPAD risk mitigation, as well as the relatively very small risk of using TPWS to mitigate overspeed derailments).

7.10 Network Rail is concerned about the safety risk that interfacing temporary equipment to safety critical signalling circuits will pose when the potential benefits from this are so small.

7.11 The current arrangements for signing and protecting all TSRs will have to be retained in full. Thus TPWS becomes additional equipment and not replacement protection.

7.12 The technical problems that would be encountered when fitting TPWS to TSRs are:

- The need to use non standard TPWS equipment, i.e. portable TPWS track equipment.
- TPWS at TSRs would place an additional demand on signal designers and technician resource to design, survey, install, test and commission the installations, and to restore the infrastructure afterwards;
- Complex TPWS installation would have to be implemented using standard OSS equipment interfaced to signalling power supplies and signal/route controls. In SSI signalled areas, it may be necessary to implement a data change or add relays to detect point positions. Complex approaches may also require multiple sets of equipment to protect a single TSR.
- The design of all TPWS TSR installations would require formal assessment using a bespoke design tool.
- TPWS cannot be used to protect the lower speeds of differential speed restrictions, where the speed restriction is only for a freight train, and would not be fitted where affected by the 'freight train timer issue' and in certain other cases.

- TSRs in rear of the TSR being protected will have an effect on the effectiveness of the protection.
- TPWS will only provide reduced protection in others cases.

7.13 The implied value of preventing a fatality (and equivalent fatalities) associated with fitment in accordance with the Regulations would lie in the range £87 million to £12.3 billion. This could be improved by a factor of approximately three by relaxing the minimum duration for which fitment was required to 1 year but the benefits are still grossly disproportionate to the costs.

8. Exemption Request

8.1 Her Majesty's Railway Inspectorate is requested to grant a certificate of permanent Exemption from the Regulations for train protection requirements at all temporary speed restrictions that are on Network Rail controlled infrastructure.

References

GK/RT0038 — Signing of Permissible Speeds and Speed Restrictions, Railway Group Standard

RMD1/TPWS/REP/500 — Submission to HMRI – Exemption of TPWS at Permanent Speed Restrictions Affected by Freight Train Timers

TPWS/SPON/5.1/238R — Network Rail request for Exemption from the Railway Safety Regulations (1999) for application of TPWS to PSRs with Approach Control Signalling

Railtrack response to Draft Railway Safety Regulations, 21 August 1998

Tony Taig Report — The Application and Effectiveness of TPWS at TSRs

Appendix 1: Derailment Risk at Speed Restrictions

This appendix provides a summary of the analysis that we have undertaken and the findings on which we have relied in Sections 2 and 3 of this document. Our analysis demonstrates that:

- There has been a steady and continuing downward trend in the risk of overspeed leading to derailments extending through the past decade as well as over previous decades.
- Evidence for this trend is supported by examination of broader trends in the larger numbers of derailments generally, and of derailments associated with Driver error in particular.
- The current risk of all fatal derailments due to overspeed is difficult to estimate, but is somewhere in the range of one accident every 20-200 years, leading to on average 0.03 to 0.3 equivalent fatalities per year.

The first part of the Appendix (Section A1) examines fatal accident statistics for derailments generally, and overspeed derailments in particular. Subsequent sections consider

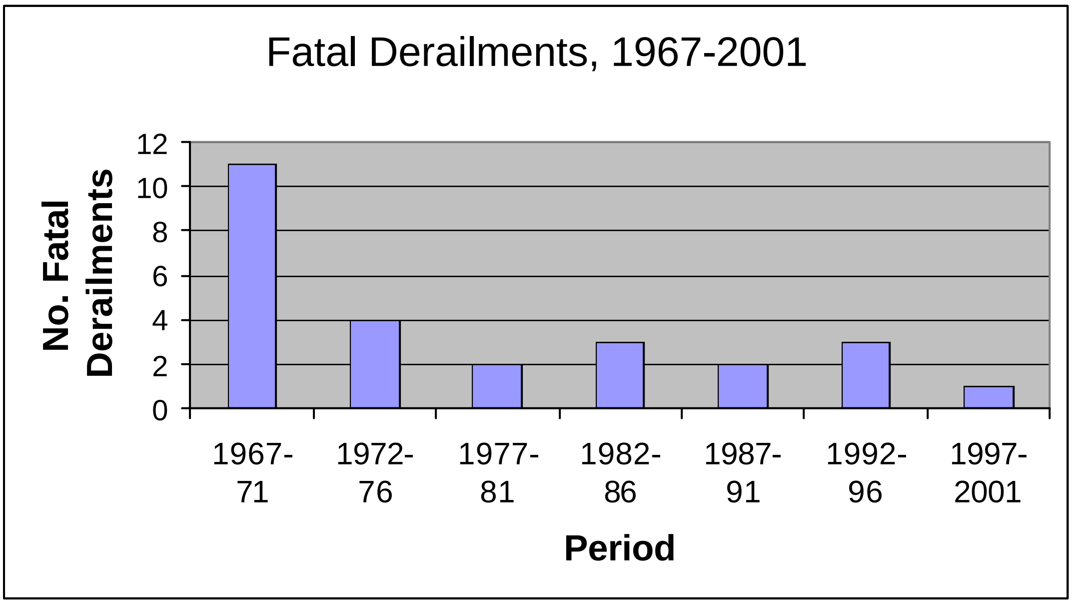
- the incidence of derailments associated with overspeeding (A2);
- overspeeding, and trends in its occurrence and management (A3);
- the current risk of overspeed derailment accidents, network-wide (A4);

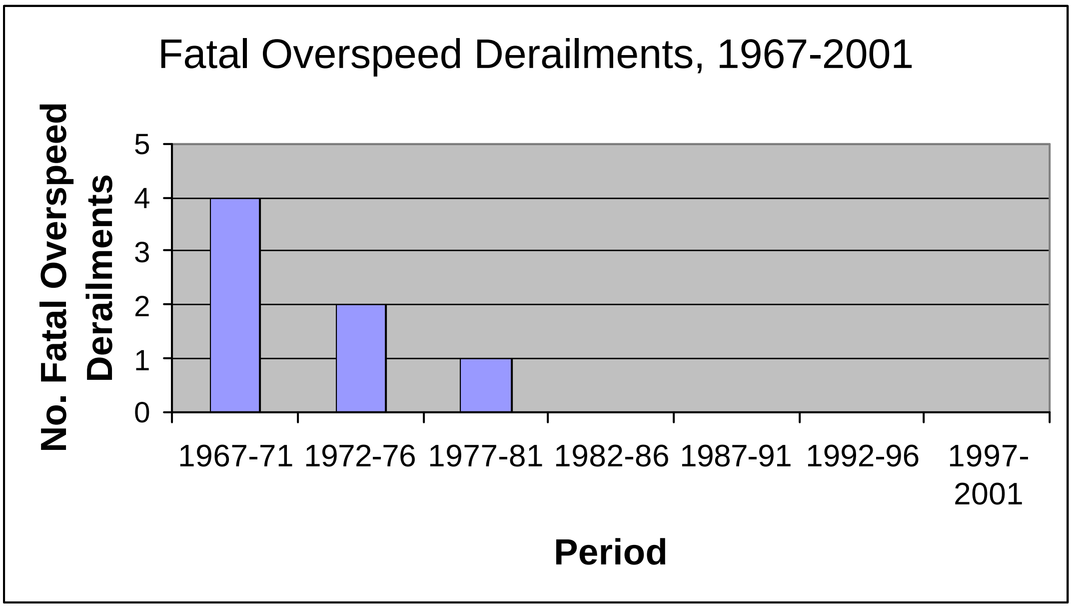
A1: Fatal Derailment Statistics

This analysis is based on the statistics on all such incidents on Network Rail's infrastructure for the period 1967-2001, produced by Prof A Evans of University College London. We are confident that his is the best available compilation of accident records.

The first figure overleaf shows the fatal derailments in the period and when they occurred (grouped into 5 year time bands – the Y axis shows the total number of incidents in each 5 year period). The second figure shows the sub-set of these incidents associated with overspeed.

One hypothesis could be that fatal overspeed derailment risk has steadily declined from the start of this period to the present day. Another would be that there was a significant fall in risk from 1967 to about 1980, but that since then the risk has been steady. Under either hypothesis, the risk of fatal overspeed derailments represents a small proportion of overall fatal derailment risk, and is currently small (one in about 100 years on the first hypothesis; one in about 10 years on the second). More confidence in this risk can be gained by extending attention to non-fatal derailment and overspeed information.

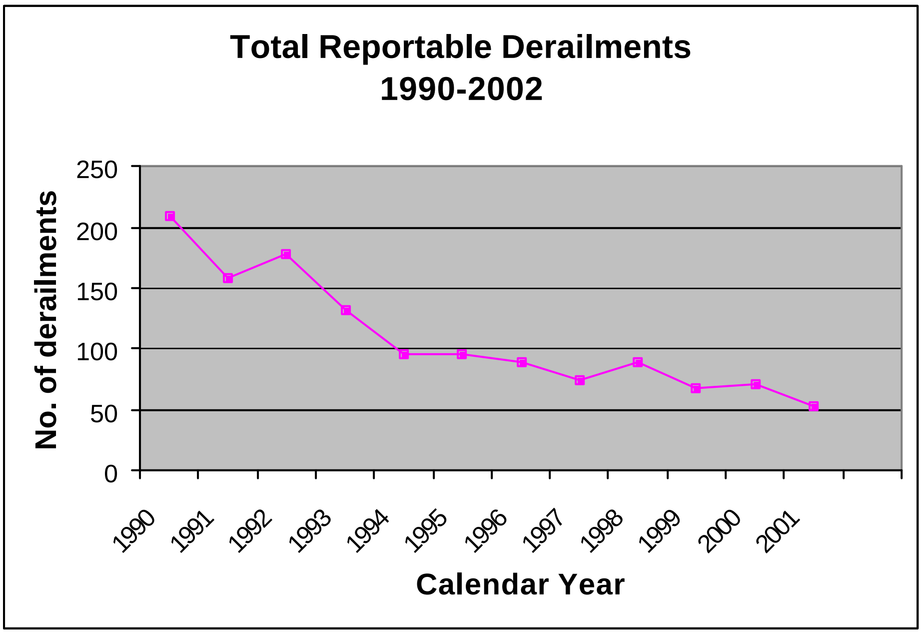


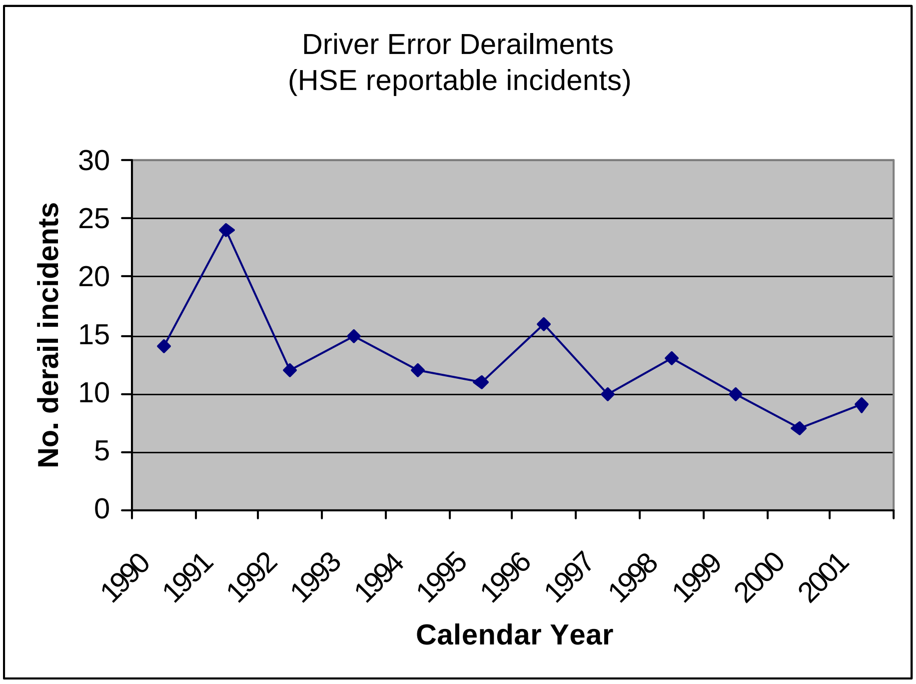


A2: Non-Fatal Derailments due to Overspeeding

The trends in overall derailments reported to the Health and Safety Executive from 1990 to 2001, and in the sub-set of those derailments involving Driver error, are shown in the Figures below:

A "best fit" statistical analysis assuming constant annual percentage reduction indicates that the current rate of reportable derailments is about 60-70 per year, decreasing annually by 11-12%. The corresponding current best estimate rate of Driver error derailments is about 10 per year, falling at 5-6% annually.





Reportable derailments due to overspeeding from 1990 to 2001 are summarised in the table overleaf:

There were 9 such incidents (just under 1 per year), which is too few to establish a trend over the period. Other important features of this set of 9 non-fatal reportable accidents include:

DATE	Location	REMARK
21/05/1992	EFFINGHAM JUNCTION/BOOKHAM	Derailed due to overspeed
13/04/1993	TOWNHILL	Driver drew power within speed restriction resulting in five wagons becoming derailed
23/09/1993	MANCHESTER PICCADILLY STN	Derailment caused by excessive speed
27/06/1994	MORPETH	Class 47 hauled express parcels train derailed after driver exceeded speed restriction on curve by 25mph
14/03/1995	ELSHAM	Eight freight wagons derailed on uneven track (within tolerances) due to overspeed
24/07/1995	SKELTON BRIDGE	Diesel loco hauled train derailed due to excessive speed
13/12/1995	SHOEBURYNESS	Main line blocked by derailment of empty coach stock due to excessive speed.
27/01/1996	CWMGWRACH	Empty coal train consisting of 2 x class 37 locos and 36 empty wagons did not stop at mandatory stop board and derailed on facing points due to excessive speed - line speed 20 mph.
29/06/1999	KNUTSFORD	Goods wagon derailed due to excessive speed and train formation. There was evidence of a rail defect, but this was not thought to be the cause of the derailment.

- Morpeth 1994 was a very serious event, which could easily have been fatal
- a significant cause of overspeed is accelerating into or while in a speed restriction (Townhill, Elsham, Cwmgwrach)
- a significant proportion (5 or 6 out of the 9) involved overspeeding at a speed restriction.

A larger set of statistics on derailments associated with overspeed, including incidents not reportable to HSE, was obtained from RSSB's Safety Management Information System (SMIS). For the period from 1990 to 2001 there were a further 14 non-fatal overspeed derailments not reportable to HSE:

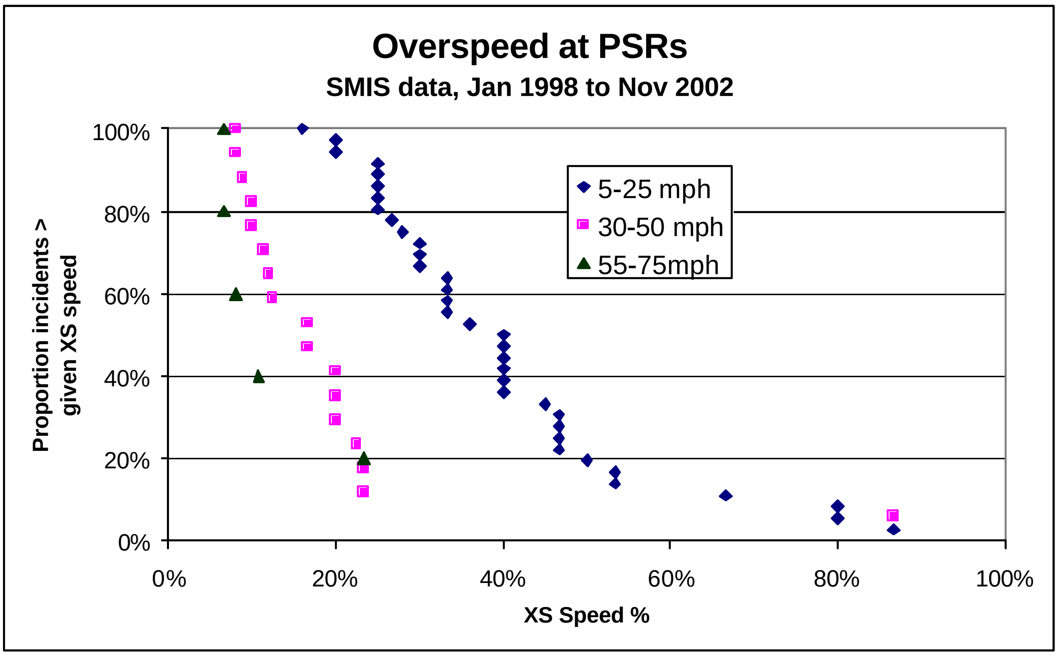
- Chelford 31/7/1990
- Torrybury 17/2/1993
- Plumley 22/2/1993
- Grove Park 3/9/1993
- Maidstone East 6/9/1993
- Dartford 19/4/1994
- Didcot Parkway 4/10/1994
- Kirkland East 28/11/1994
- Newton Heath depot 6/10/1998
- Tyseley No. 1 17/2/1999
- Newton 8/3/1999 (buffer stop collision)

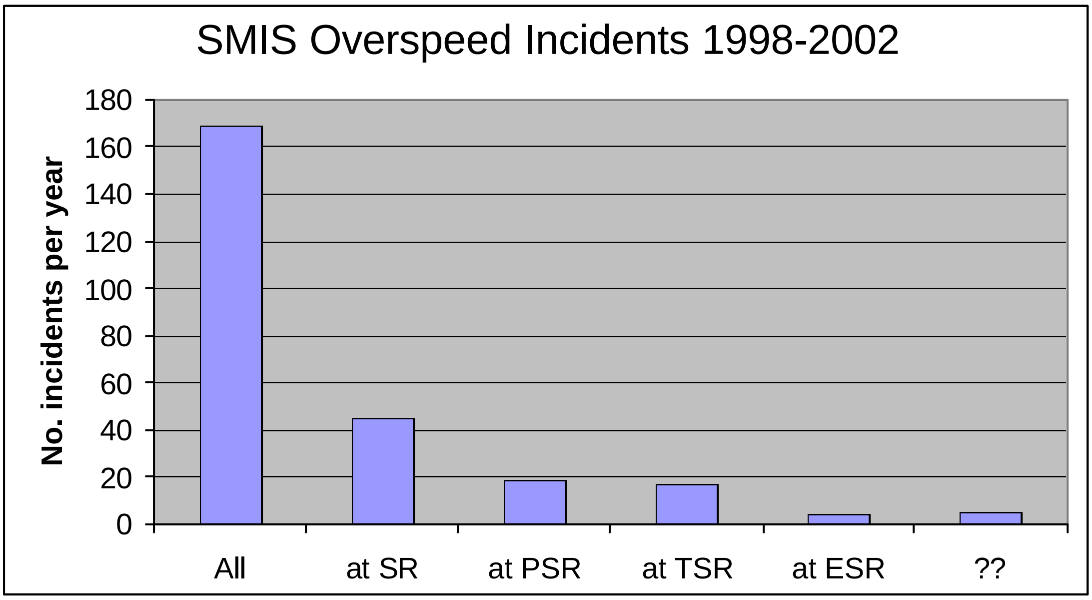
- Barry Dock 22/6/1999
- Wigan Wallgate 6/10/1999
- Oxenholme 10/3/2002

The conclusion was that non-fatal overspeed derailments occur at a rate somewhere between about 1 and 3 events per year.

A3: Overspeeding (without derailment)

From time to time train operators and Network Rail monitor overspeeding using radar speed guns. Serious overspeeding is also reported by people working on or around the track, to whom it presents a serious risk. Details of overspeeding incidents are collected in the RSSB SMIS system. A summary of recent such incidents is provided in the chart and tables below.





Analysis of SMIS Overspeed Incidents at PSRs

SUMMARY:	**SR**	**No. OS's**	**Ave Speed**	**Ave OS, as % PS**	**Max OS above PS**	**Max OS%**
PSR incidents where	10	4	15.3	53%	8	80%
speed recorded	15	16	21.8	45%	13	87%
19/1/98 to 25/11/02	20	16	26.7	33%	16	80%
	25	5	31.3	25%	9	36%
	30	9	38.5	28%	26	87%
	35	1	39.0	11%	4	11%
	40	2	47.0	18%	9	23%
	45	2	49.0	9%	4	9%
	50	5	54.8	10%	6	12%
	60	1	74.0	23%	14	23%
	65	1	72.0	11%	7	11%
	75	3	81.0	8%	6	8%
	80	1	86.0	8%	6	8%
TOTAL		66				
Total > 30 mph		16				
Total </= 30 mph		50				

This information, and other wider studies of overspeeding, do not provide a reliable quantitative guide to how often overspeeding occurs, because only a small sample of trains are monitored. They do, though, support the qualitative conclusions that

- serious overspeeding is very rare (bearing in mind the need for at least 50% excess speed for derailment to become a risk), and
- compliance at PSRs is good, given the large numbers of them on the network in relation to the modest proportion of overspeed incidents they represent.

This second conclusion has been corroborated by a detailed analysis, in which we printed out, read and categorized the records of reported overspeed in SMIS in recent years to learn as much as we could about overspeeding and its characteristics.

While statistics do not allow the trend to be quantified precisely, it is clear that overspeeding has been brought under much better control over the past 30-40 years by advances in technology and in Driver management and behaviour. Significant developments have included:

- introduction of radar speed checks (20-40 years ago)
- introduction of lineside speed signing (post 1945)
- improved Driver selection processes and competence management systems (last 10-20 years)
- introduction of train data recorders (last 10-20 years)
- drug & alcohol abuse changes (last 20-30 years, in society as well as the railway), and
- formal introduction of defensive driving training & policies (last 5 years).

A4: Overall Frequency of Overspeed Derailments, Network-wide

We are faced with a small but uncertain risk, today, of overspeed derailments generally and of fatal incidents in particular. The range of estimated annual frequencies of fatal overspeed incidents is wide, from less than one per 200 years, to more than one per 10 years. Arguments for the lower and higher ends of the range in the table below.

Arguments for LOWER end of range	Arguments for HIGHER end of range
• Reportable derailments overall have shown significant continued downward trend since 1990 • Driver error derailments have done likewise • Non-fatal overspeed derailments are themselves rare (1-3 per year) and only a small proportion are high speed, risky events • Ability to monitor & manage Driver overspeeding has improved enormously in past 2 decades • Social & cultural trends (e.g. drug & alcohol policies) should have further reduced Driver adverse behaviour including overspeeding	• No evidence that fatal derailments show downward trend overall post-1976 • Absence of overspeed fatal derails since 1982 could be just chance • Morpeth incident in 1994 was close to causing a fatality

Our judgement is that the risk of a fatal overspeed derailment, anywhere on Network Rail's infrastructure, is currently somewhere in the range of 1 in 200 years to 1 in 20 years.

Appendix 2: Analysis of Overspeed Incidents

A2.1 Source Data

A SMIS report was produced for incidents of train overspeed from 1/1/98 to 23/1/2003.

There were 844 incidents, with a small number of incidents referring to more than one overspeeding train.

A2.2 Compilation of Spreadsheet

Data was manually extracted from the SMIS report. Incidents of trains overshooting signals and platforms were excluded, as generally train Drivers were aware of the need to adjust their speed, but left braking too late. In recent months there have been incidents of TPWS tripping trains that were travelling in excess of the speed set by TPWS. These incidents have been excluded because of the over sensitivity of some installations, e.g. buffer stops; and because Drivers are having to modify their techniques to ensure complete compliance with signals and PSR approach speeds where TPWS is fitted.

Incident records where data is incomplete for the speed analysis were also excluded. The total number of excluded records is less than 1% of the total number of incidents.

The spreadsheet was analysed containing a sample of the SMIS incident records, and records 421 incidents of individual train overspeeds.

A2.3 Results

The number of incidents reported each year, and average overspeed, are shown in Table A2.1:

Table A2.1: SMIS Overspeed Incidents Analysed

Year	No of incidents reported	Average overspeed per incident (mph)
1998	138	9.6
1999	97	10.7
2000	70	14.2
2001	70	9.7
2002	46	15.2
Total	421	11.2

From the SMIS data the following categories of speed restrictions were identified:

Linespeed	Track linespeed, and this category was used as a default where type of speed restriction was not stated in the SMIS report.
PSR	Permanent Speed Restriction (In many instances these are synonymous with linespeed).
TSR	Temporary Speed Restriction
ESR or EROS	Emergency Speed Restriction or Emergency Restriction of Speed. These have the same effects as TSRs, although they may not be published in the WON, and depending on the duration of the ESR/EROS the protection measures may not be as extensive as for TSRs.
Vehicle Speed Restriction	These are the speed restrictions imposed on particular vehicle or formations of vehicles, and may restrict the train to speed lower than the prevailing permitted speed.
Work force speed protection	These are incidents where the SMIS report identified the purpose of the speed restriction was to protect workers on the line along which the offending train travelled, or to restrict the speed of trains on lines adjacent to where work was taking place. In many instances TSRs and ESRs/EROSs must have been imposed for this reason, but this was not stated in the SMIS report.

The analysis of the speed restriction category is shown in Table A2.2:

Table A2.2: Overspeed Incidents & Speed Restrictions

Type of Speed Restriction	Incidents %	Average Excess Speed (mph)	Maximum Excess Speed (mph)
Linespeed	37	7.5	30*
PSR	27	7.4	32*
TSR	25	19.0	55*
ESR/EROS	5	17.0	70
Workforce Protection	1	21.7	55
Vehicle	5	10.8	35*

** Maximum shown was validated by radar or train borne black box, others were from speed estimates by observers.*

The distribution of incidents by permitted speed and by excess speed is shown in Table A2.3 (a) and (b) respectively.

Table A2.3: Overspeed Incidents: by Permitted Speed & by Excess Speed

(a) Permitted Speed Analysis

Permitted Speed (mph)	*No of Trains*
Up to 10	56
11 – 20	180
21 – 30	55
31 – 40	27
41 – 50	33
51 – 60	29
61 – 70	4
71 – 80	20
81 – 90	6
91 – 100	2
101 – 110	3
111 – 120	Nil
Over 120	1

(b) Excess Speed Analysis

Excess Speed (mph)	*No of Trains*
Up to 10	293
11 – 20	64
21 – 30	18
31 – 40	19
41 – 50	10
51 – 60	Nil
61 – 70	2
Over 70	Nil

62 trains or 15% of all incidents reported involved train speed of 60 mph or over. The excess speeds in these incidents are tabulated in Table A2.4 below.

Table A2.4: Excess Speeds for 60mph+ Incidents

Excess Speed (mph)	No of Trains
3	1
4	8
5	13
6	10
7	10
8	3
9	2
10	1
11 – 15	8
16 – 20	4
21 – 30	Nil
31 – 40	1
Over 40	Nil

For permitted speed of 60 mph and over the average excess speed is 8.6 mph.

The statistics include large numbers of incidents with small reported overspeeds, and a significant number with much larger reported overspeeds. The vast majority of the former involve speed detection by regular radar speed checks carried out by train operators or Network Rail, while the latter often involve eye witness reports from track workers or signalling operators. The breakdown of incidents by source of report is shown in Table A2.5.

Table A2.5: Sources of Incident Reports Analysed

Reporter	Proportion of reports	Average excess speed reported (mph)
Radar Checks	77%	7.9
Track Works (& other lineside observers)	17%	28.2
Signallers	5%	22.3
Others	1%	

Appendix 3: Track Worker Risk Fitting TPWS

A3.1 Introduction

The purpose of this appendix is to estimate the level of risk per hour at trackside faced by staff required to put out, maintain, modify or remove TPWS loops. It has been prepared by Tony Taig of TTAC Ltd on behalf of Network Rail's TPWS programme, in particular connection with a current assessment of options for fitment of TPWS at Temporary Speed Restrictions (TSRs). It updates (and gratefully acknowledges) an earlier assessment carried out by Sedgwick Wharf[7]. The appendix explains

- the approach adopted to the assessment (A3.2)
- the estimation of hourly risk per exposed person (A3.3), and
- conclusions as to the level of that risk (A3.4).

A3.2 Approach

The approach adopted is as follows:

1. Consider which movement and non-movement hazards (from the set contained in RSSB's current Risk Profile Bulletin) are pertinent to staff working on TPWS
2. Take current (historic) levels of relevant risk per year across the network from the current Risk Profile Bulletin
3. Derive from these the current (historic) levels of relevant risk per hour for green and red zone working using "time spent in green & red zone" data from RSSB's latest Safety Performance Report
4. Assume TPWS work will take place under green zone conditions, and
5. Extrapolate future levels of green zone risk from current (historic) levels based on reasonable assumptions as to the likely effects of recent changes to management of work at the trackside, in particular the adoption of the new RIMINI standard.

This latter is important in any argument setting the increment in track worker risk against the possible safety benefits of installing or altering TPWS. Any such argument would be weakened were historic, network average track worker risk levels used, as it is reasonably foreseeable even at this early stage in adoption of RIMINI that not only is the proportion of green zone work increasing, but also the risk associated with both green and red zone work is decreasing with better planning and management of work on the track.

A3.3 Estimation of Risk

Table 1 shows the top events from the RSSB Risk Profile Bulletin that might potentially be significant for staff installing or altering TPWS loops, based on the entire set of "risks at trackside" considered in Network Rail's RSSB Case.

[7] "TPWS: Net Safety Effects at Temporary Speed Restrictions", Sedgwick Wharf, October 2002

Table 1: Risks Relevant to Staff Working on/around the Track
(Network Rail Safety Case)

Event	TPWS Relevant Risk/yr			
	Fatalities	Major Injuries	Minor Injuries	Total EF
HEM 14: Traincrew struck by train	0.14	0.75	0.57	0.22
HEM 16: Traincrew falling while boarding or alighting	0.00	6.74	240.00	1.87
HEM 19: Worker struck by train	2.25	2.25	3.37	2.49
HEM 20: Worker struck by flying object	0.00	8.34	218.00	1.92
HEM 21: Worker falls between train & platform	0.00	1.67	69.00	0.51
HEN 24: Worker trips, slips & falls trackside	0.33	57.00	1064.00	11.35
HEN 25: Worker falls from height	0.05	3.18	12.70	0.43
HEN 28: Worked exposed to arc from OLE or conductor	0.00	1.70	15.00	0.25
HEN 30: Worker in contact with conductor rail	0.17	2.33	6.00	0.43
HEN 31: Worker in contact with OLE	0.33	0.67	1.00	0.40
TOTAL Risk to Staff on & around the Track	**3.27**	**84.63**	**1629.64**	**19.88**

Table 2 shows an assessment of the relevance of these various elements of risk to staff working on TPWS loops. In this assessment we were able clearly to identify hazards of no relevance to TPWS fitment, but also were unable to identify factors for TPWS fitments generally that should make them more or less risky than the generality of trackside activity.

Table 2: Relevance of Trackside Risks to TPWS Installation

Event	TPWS multiplier	Rationale
HEM 14: Traincrew struck by train	0.0	Not relevant to staff installing TPWS
HEM 16: Traincrew falling while boarding or alighting	0.0	Not relevant to staff installing TPWS
HEM 19: Worker struck by train	1.0	TPWS installation typical of green zone work
HEM 20: Worker struck by flying object	1.0	TPWS work typical of trackside work generally
HEM 21: Worker falls between train & platform	0.0	Not relevant to staff installing TPWS
HEN 24: Worker trips, slips & falls trackside	1.0	TPWS work typical of trackside work generally
HEN 25: Worker falls from height	0.0	Not relevant to staff installing TPWS
HEN 28: Worked exposed to arc from OLE or conductor	1.0	TPWS work typical of trackside work generally
HEN 30: Worker in contact with conductor rail	1.0	TPWS work typical of trackside work generally
HEN 31: Worker in contact with OLE	0.0	Not relevant to staff installing TPWS

Table 3 shows the main assumptions used to estimate current levels of (pre-RIMINI) green zone risk per person per hour at trackside[8].

Table 3: Key Assumptions to Estimate Current (pre-Rimini) Green Zone Risk

Parameter	Upper[1]	Lower	Basis
Total man-hours spent trackside pre-Rimini per year:	45000000	50000000	RSSB Annual Safety Performance Report 2002/03, Table 35
% Time red-zone pre-Rimini per year (beta)	0.60	0.50	
Green Zone casualties as proportion of total casualties	0.35	0.27	

Note 1: "Upper" & "Lower" defined in relation to the direction in which they "push" Green Zone risk

Note 2: Upper & Lower ranges for Green Zone casualties derived from Table 35 by considering the effect if either one less or one more fatality had occurred in Green Zones than the 8 out of 26 fatalities recorded in the Table.

[8] I estimated the proportion of casualties within Green Zones as 0.27 to 0.35, based on the 8 out of 26 fatalities in Green Zones (8 out of 26 implies a proportion of 0.31; one fatality in a green zone not a red zone or vice versa would have led to proportions of 0.35 or 0.27 respectively) shown in Table 35 of the RSSB SPR, 2002/03.

On this basis it is estimated that current (pre-RIMINI) risk levels per hour for each of the relevant top events in Tables 1 & 2 are as shown in Table 4 overleaf. The table provides a range of estimates within which it is difficult to discriminate where the risk might actually lie (Note – these are by no means absolute bounds on risk, which will vary significantly from place to place, task to task and person to person).

It now remains to estimate the likely effect of RIMINI and associated changes on track worker risk. A range of estimates have been made of the maximum and minimum likely effect of RIMINI, which shows their implications for the range of worker risk per hour (post-RIMINI) likely to apply to green zone working on TPWS loops, in Table 5 overleaf.

- New patterns of work and improved planning are leading to significant reductions in minor (precursor) type incidents relevant to workers being struck by train.
- HSE have commented on improved planning and organisation of work in both green and red zones
- The changes are designed particularly to reduce risk of workers being struck by trains (HEM 19) but should produce similar scale benefits in respect of other risks associated with hazardous activity around the track (this includes an extension of parallel assumptions to electrocution related events, and 50% of the associated benefit to HEM 19 to events associated with track workers being struck by flying objects)
- The only potential downside in all this is that there has been a significant increase in work being done at night, which might lead to a modest increase in slips, trips and falls (though there is no hard evidence for this as yet).

The estimates of RIMINI effect, and thus of future TPWS-relevant green zone risk per hour, shown in Table 5 are rough and ready, but should serve to indicate the sort of range of average risk levels under which future TPWS work is likely to be carried out

A3.4 Conclusion

The likely range of risks track workers installing or altering TPWS loops will face in future is about

2 to 5 x 10^{-8} fatalities per hour, or

3 to 4 x 10^{-7} equivalent fatalities per hour.

The dominant contributor to both risks is slips, trips and falls at the trackside, but being struck by a train is also a significant contributor to the fatality risk. Fatality risk is correspondingly more uncertain than EF risk, because of the greater likely (but hard to quantify) impact of RIMINI and other new practices on this hazard.