Sotera
Risk Solutions

Report for Network Rail

Risk Assessment of the Crossrail Train Protection Strategy – Paddington to Heathrow for 2018

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REVISIONS

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Rev 00	Peter Dray			Internal version
Rev 01	Peter Dray	David Harris	15/11/2015	Internal accounting for Mk3 and Mk4 units
Rev 02	Peter Dray	David Harris	18/11/2015	Draft - Issued to Network Rail for review
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1 INTRODUCTION

Crossrail is planning for the operation of train services between Paddington and Heathrow airport, with services due to commence in May 2018. Crossrail trains (Class 345) will replace the existing Heathrow Connect services and increase the peak time number of trains per direction from two trains per hour to four trains per hour.

It was anticipated that the route would be provided with ETCS in time for the commencement of the service, such that when the existing Heathrow Connect ATP fitted train service is replaced, an equivalent level of protection against SPADs/overruns would be provided by ETCS. This option is the preferred solution and for the purposes of this report is referred to as 'Plan A'. It is possible that ETCS may not be provided on the route by May 2018, and therefore fall-back plans are required to ensure an equivalent level of safety performance for passengers and staff can be maintained. The following cases are assessed within this report:

- 'April 2018', this is a reference case which represents the proposed operation prior to the introduction of Crossrail services. Hence the Heathrow Connect services would be operational and protected by ATP. The services operated by Heathrow Connect would be at approximately half the frequency of the proposed Crossrail services.

- 'Plan A', refers to the case where ETCS is provided between Paddington and Heathrow and Crossrail trains are fitted with ETCS. For plan A, no additional TPWS is provided. Trains would operate to the May 2018 timetable.

- 'Do nothing', this refers to the scenario where ETCS is not provided by May 2018 and no additional TPWS is provided. In this case the Crossrail trains would be provided with Mk4 TPWS in-cab units. Trains would operate to the May 2018 timetable.

- 'Plan B', refers to the case where ETCS is not provided by May 2018. Enhanced levels of TPWS protection would be provided; signal TPWS would be designed to stop trains with 12%g emergency braking within the signal overlap. Furthermore, extra TPWS would be provided on the approach to buffer stops. No additional TPWS would be provided for permanent speed restrictions. Crossrail trains would be provided with Mk4 TPWS in-cab units and operate to the May 2018 timetable.

Sotera has been commissioned to undertake a detailed, independent, risk assessment of the above train protection strategies. The risk assessment focusses on four key areas of risk, which are train-train collisions from SPADs, derailments from overspeeding, buffer collisions and the risk to maintainers from servicing additional TPWS trackside units. These are considered to be the hazardous events significantly affected by the proposals.

This report provides the results and findings from the risk assessment.

2 SCOPE OF THE ASSESSMENT

The scope of work is described in the following sections.

2.1 Physical boundary of the operation

The boundary covers train operation of passenger and freight services over Network Rail infrastructure on the passenger lines between Heathrow Airport Junction and Paddington (0MP to 12MP). This includes:

- Up Main line
- Down Main line
- Up Relief line
- Down Relief line
- Lines to platforms 1 to 14 at Paddington
- The 'Airport Lines' as far as Airport Tunnel Junction.

The layout is as described in the following scheme plans:

- Thames Valley Signalling Centre Southall to West Dawley (9½ to 12½ MP) Scheme Plan (Crossrail Grip 4). Ref. 10-GW-033-06, Version A2.
- Thames Valley Signalling Centre Hanwell Bridge to Southall Station (7½ to 9½ MP) Scheme Plan (Crossrail Grip 4). Ref. 10-GW-033-05, Version A1.
- Thames Valley Signalling Centre West Ealing, Hanwell and Elthorne (6½ to 7½ MP) Scheme Plan (Crossrail Grip 4). Ref. 10-GW-033-04, Version B1.
- Thames Valley Signalling Centre Acton to Ealing Broadway (3¾ to 6½ MP) Scheme Plan (Crossrail Grip 4). Ref. 10-GW-033-03, Version A4.
- Crossrail ONW Old Oak Common (2¼ to 3¾ MP) Scheme Plan (Crossrail Grip 4). Ref. 10-GW-033-02, Version B.
- Crossrail ONW & IEP Integration Paddington (0 to 2¼ to MP) Scheme Plan (IEP Grip 4). Ref. 10-GW-033-01, Version B.

2.2 Hazardous Events assessed

The significant 'Train Movement' accidents that may be impacted by the train protection strategy are included, specifically:

- Collision between trains
- Derailments due to overspeeding
- Buffer collisions.

Additionally, risk to maintainers of TPWS equipment is included together with related construction activities.

2.3 Service Levels

Two timetables are analysed for the assessment; the 'April 2018' and 'May 2018' timetables. The key difference between the two is that the 'April 2018' case has two Heathrow Connect trains per hour per direction between Paddington and Heathrow, whereas the 'May 2018' case has replaced the Heathrow Connect service with four Crossrail trains per hour per direction. The timetable usage applied in the model is taken from previous timetable analysis completed for Network Rail in a spreadsheet named '122271-ISD-SKE-ESG-00001.xls'. The spreadsheet contains an analysis of a wide range of timetables for each service that operates within the boundary of the project to determine the routing of trains through the layout. The timetable data is termed the 'Simplified Timetable Information SX 0700-1900 for ETCS "TPWS Plan B" Study for April' and 'for May 2018'.

3 APPROACH TO THE RISK ASSESSMENT

3.1 Overall approach

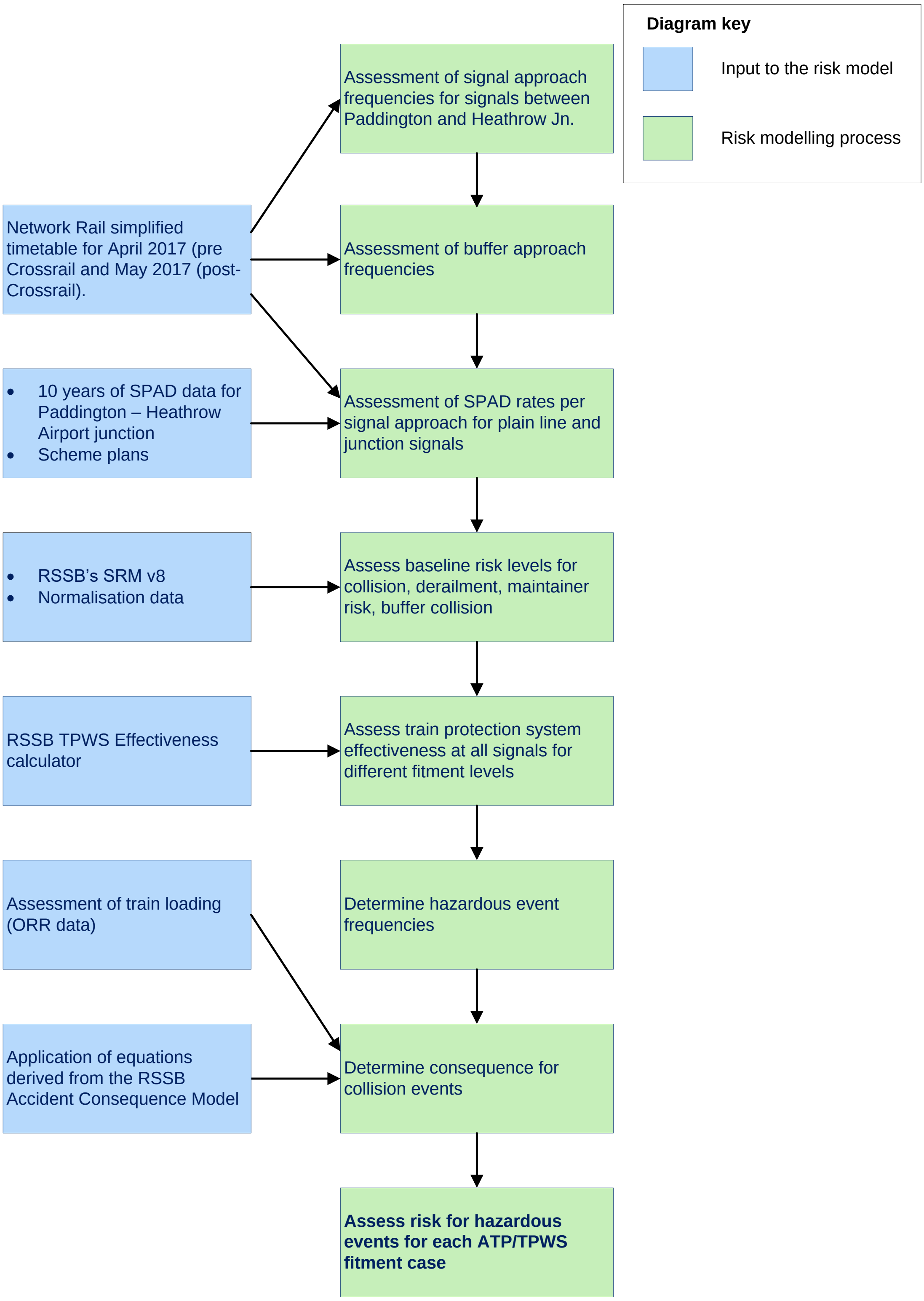
This section describes the approach to the risk modelling for each hazardous event.

A range of data analysis techniques were used to determine the risk from each of the hazardous events analysed for Crossrail. Separate models were developed for each of the hazardous events assessed. Of the hazardous events, the most sophisticated model is for train collisions resulting from SPADs.

The main stages to the assessment are presented in Figure 1. The inputs are shown in blue and the main process stages shown in green. The following subsections describe the approach for each hazardous event.

The key study assumptions are presented in Section 5.

Figure 1 The key elements and data input the risk model



3.2 Train-train collisions

The train-train collision model is the most complicated of all the hazardous events assessed. The reasons for this are the need to account for the number of train approaches to each signal, the wide range of rolling stock and the effectiveness of ATP or TPWS at each signal for the trains operating past the signal. The main elements of the model are described below:

The likelihood of SPADs at each of the signals

This assessment is based upon the signal type (plain line or junction), the number of approaches to the signal and the likelihood of a SPAD per approach. The likelihood of a SPAD per approach has been based on historic SPAD performance at the signals subject to assessment accounting for ten years of SPAD performance data in the route section between Paddington and Heathrow Airport Junction. The predicted SPAD rate is apportioned to each signal by the frequency of train approaches; this is done separately for junction and plain line signals as the SPAD rate tends to be much greater at junction signals. The overall SPAD rate per signal approach (combining both plain line and junction signals) is very similar to the calculated average for the network; the network figure is 5.0×10^{-7}, whereas the Paddington to Heathrow value is 4.4×10^{-7}.

For completeness, all signals in the area have been assessed irrespective of whether they are directly impacted by the Crossrail service. The number of signal approaches is based upon analysis of the timetable for 2018 before and after the implementation of Crossrail services to Heathrow.

The likelihood of a collision following a SPAD

The model has been developed to investigate escalation of a SPAD into a train-train collision. The starting point for this is determining the likelihood that a SPAD results in a collision (for junction and plain line signals) excluding the benefit from any train protection system. Using this approach the benefit of the various train protection systems can be layered on the assessment to determine the benefit they provide at each signal. In order to determine the likelihood that a SPAD results in a collision, the SRM v8 has been used. The benefit of TPWS is inherently included in the SRM and therefore the benefit of it was factored-out by accounting for the typical performance of TPWS at plain line and junction signals.

The effectiveness of the prevailing train protection system at each signal for each of the cases accounts for the trains that pass each signal and the fitment options for TPWS and the installation of ATP. TPWS effectiveness is assessed using the TPWS effectiveness calculator developed by RSSB. The TPWS effectiveness calculator accounts for the train's braking performance, track gradient, the overrun distance required to cause a collision, the line speed, train braking performance and TSS and OSS fitment (distance from the TSS and set speed). Enhanced levels of protection are provided by Mk3 and Mk4 in-cab units (see Assumptions in section 5).

Assessment of passenger loading on trains

The passenger train loading for all services (as an average for Paddington) have been taken from ORR statistics[1] by dividing the number of passenger journeys at Paddington by the number of train services.

The assessment gives an average loading figure of 176 passengers per train, which is significantly higher than the national figure of approximately 100.

Assessment of line speed and collision speeds

In the event of a collision, an important factor in assessing the potential consequences is the likely speed of a collision. The likely collision speeds have been assessed by accounting for the typical highest line speed at each signal and accounting for the signal type. The assumption is that a junction collision will occur at three quarters of line speed, plain line collisions will occur at two thirds of line speed. This is the same assumption as used for the Chiltern train protection risk assessment and compatible with other models used to assess collision risk.

Assessment of the consequence of collisions

The likely consequences of a collision were assessed based on RSSB's accident consequence model output which can be used to determine the likely FWI, based upon the train type, speed and passenger loading. In order to manage the complexity of the model, a curve was used to fit the output of the ACM and used to apply to each route section accounting for the calculated collision speed (as described above) for each signal.

This is considered to be an assumption that is balanced between being realistic, but also slightly pessimistic as it gives consequences that are slightly higher than predicted by the SRM.

3.3 Buffer collisions

There is a large number of buffer approaches at Paddington and consideration is being given to providing additional TPWS OSS loops on the approach to buffers. The underlying level of risk has been calculated based upon the SRM using normalisation, based upon the frequency of buffer approaches. Typically, on approach to buffers, a single TPWS OSS is provided at 55m from the buffer, set to 12.5mph. The benefit of providing additional TPWS OSS's at increased distances, set to higher speeds to trap an increased proportion of overspeeding trains has been

[1] ORR Data Portal, ORR annual statistics 2013/14 - entrances plus exits plus interchanges.

assessed through a review of the causes of buffer collisions within the SRM. The causes related to potentially high speed approaches that may not be mitigated by the standard fitment, but could be mitigated by an emergency brake application, have been assessed to be mitigated by up to 95% by the provision of additional OSS's, ATP or ETCS.

The causes of buffer collisions that may be impacted by enhanced protection are presented in Table 1.

Table 1 The causes of buffer collision and potential for further mitigation

Cause (or cause group)	Potentially mitigated by additional protection
Cases related to roll-back collisions (inherently low speed)	✗
Causes related to train set-up, coupling and uncoupling	✗
Driver selects reverse instead of forward	✗
Communication error	✗
Driver error while propelling	✗
Defective brakes	✗
Low adhesion	✗
Driver medical condition on approach	✓
Driver inexperience	✓
Defective train control system	✗
Driver loss of concentration	✓
Runaway train	✗
Error in possessions	✗

For the assessment of SPAD risk, leading to collisions, it was possible to use data for the lines between Paddington and Heathrow Airport junction. For buffer collision, there is not a statistically significant number of reported events to use data specifically for approaches to Paddington. For example, from a review of the data in RSSB's Annual Safety Performance report for 2014/15, there was no reported buffer collision on the entire network in the year.

3.4 Derailment due to overspeeding

There are many causes of derailment that are analysed within RSSB's Safety Risk Model. The only cause assessed for this study is derailments due to overspeeding as these are influenced by the train protection strategy.

Derailment from overspeeding is assumed to be as a result of exceeding the permitted line speed for a particular train type and route section. For the purposes of this assessment, where ATP is fitted, there is considered to be negligible potential for overspeeding related derailments. For services not protected by ATP, the underlying rate of derailments per train km from the SRM is used for passenger and freight trains.

It should be noted that for Plan B there is no additional fitment of TPWS for permanent speed restrictions. Hence Plan B provides no benefits over the 'Do nothing' case for this hazardous event.

The consequences of a derailment have been taken as the average for the SRM, but scaled-up to account for the higher than average calculated train loading (see Section 3.2).

Within the assessment of derailment due to overspeeding, ETCS is assumed to give the same level of protection as ATP.

3.5 Maintenance worker risk and construction worker risk

A consequential risk from the provision of additional TPWS equipment is an increased exposure of track workers to various hazards associated with working on the track whilst undertaking maintenance and the testing and repair of trackside units. An assessment of the increased risk has been determined using the SRM. In particular, those risks that a track worker undertaking such work is exposed to have been identified from the SRM. The SRM risk is normalised by track worker hours and therefore the risk increment has been determined by assessing the maintenance time required to service the additional trackside units.

Construction worker risk has been assessed in a similar way to maintenance worker risk, by determining the number of hours that workers are exposed and multiplying by the risk per hour as determined from the SRM.

The number of hours per activity are summarised in Table 2.

Table 2 Maintenance and construction hours for each option

Case	Number of loops to maintain	Maintenance hours per year	Construction hours
April 2018	324	220	0
Do nothing	324	220	0
Plan B (60 additional loops)	384	261	480 (120 shifts)
Plan A	324	220	Unknown

Note: The maintenance data in the above table is based upon Report for Network Rail from Vertex Systems Engineering, Crossrail ETCS Final Option Selection, Version 1.4, dated 24 March 2015.

4 RESULTS

The risk assessment results in this section are presented for the following cases:

- 'April 2018'
- 'Plan A' for May 2018
- 'Do nothing' for May 2018
- 'Plan B' for May 2018

Each of these cases is described in Section 1.

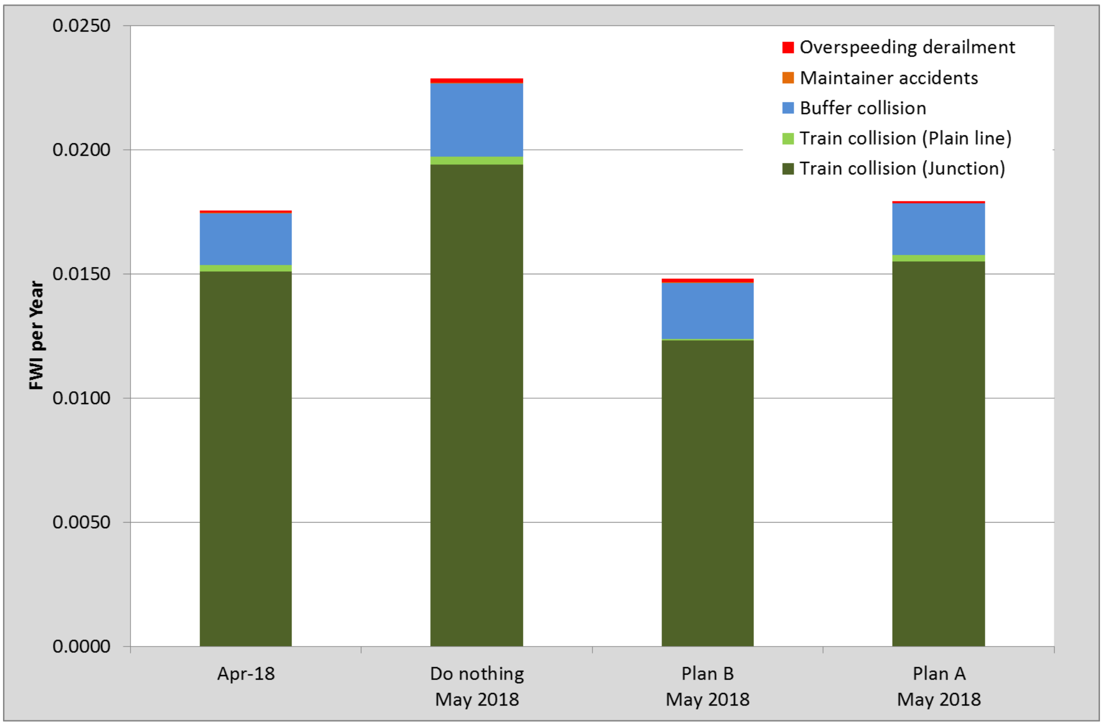
The risks from the four cases are presented in Table 3 and Figure 2 below. The maintainer risk shown refers only to the maintenance of TPWS loops, which increases slightly for Plan B due to the enhanced fitment. In addition to the annual risks there is a small, one-off, construction risk from Plan B resulting from the installation of additional TPWS loops, shown at the bottom row of the table.

The train-train collision risk is shown, per signal, in Annex A.

Table 3 Results of the risk assessment

Hazardous Event	Scenario annual risk (FWI per year)			
	April 2018	Do nothing May 2018	Plan B May 2018	Plan A May 2018
Train-train collision	**0.0154**	**0.0197**	**0.0124**	**0.0158**
Junction	*0.0151*	*0.0194*	*0.0123*	*0.0155*
Plain line	*0.0002*	*0.0003*	*0.00004*	*0.0002*
Buffer collision	**0.0021**	**0.0030**	**0.0023**	**0.0021**
Maintainer accidents	**0.000028**	**0.000028**	**0.000033**	**TBC**
Overspeeding derailment	**0.000108**	**0.000159**	**0.000159**	**0.000108**
Total	**0.0176**	**0.0229**	**0.0148**	**0.0179**
Risk increment (FWI/yr)	**-**	**0.0053**	**-0.0027**	**0.0004**
Risk increment %	**-**	**30.2%**	**-15.7%**	**1.6%**
Hazardous Event	**Scenario one-off risk (FWI)**			
	April 2018	**Do nothing May 2018**	**Plan B May 2018**	**Plan A May 2018**
Construction Risk (FWI)	**-**	**-**	**0.00006**	**TBC**

Figure 2 Results of the risk assessment



The safety benefit from the Plan B TPWS enhancements compared to the 'Do nothing' case, for each hazardous event, is presented in Figure 3. Similar information is presented in Figure 4, which compares the safety benefits with the risk increment to track workers from maintaining the additional TPWS loops. This shows that the maintainer risk disbenefit is very small when compared with the safety benefit of providing the TPWS loops.

Figure 3 The benefits of the TPWS enhancements from Plan B (FWI per year)

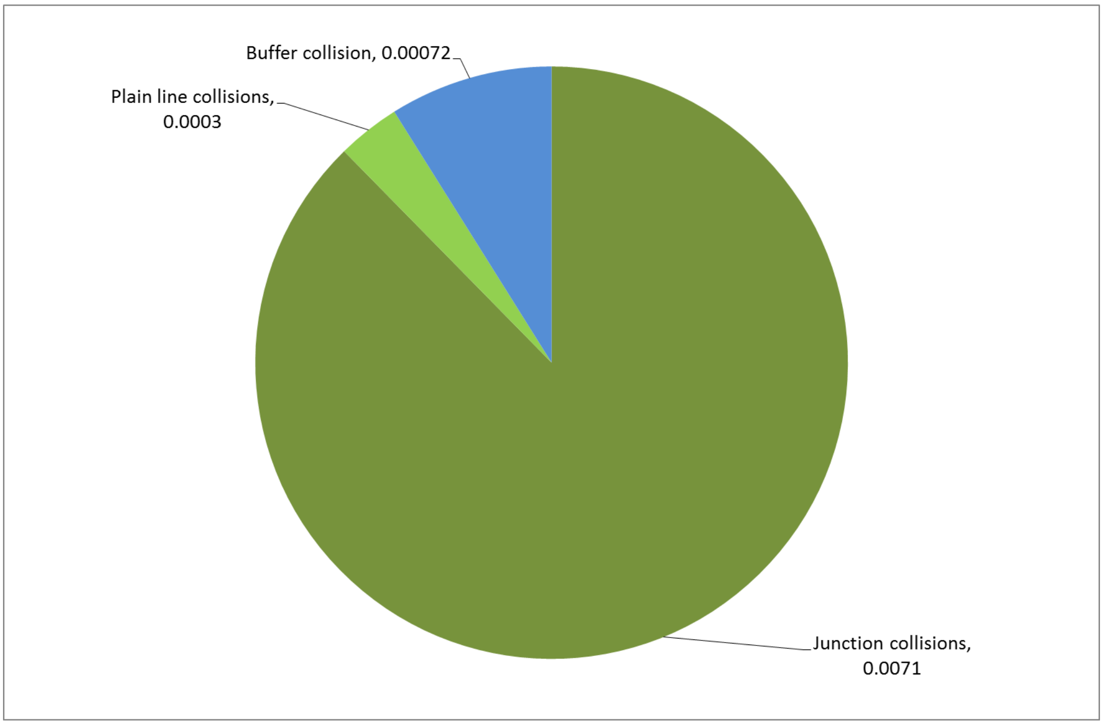
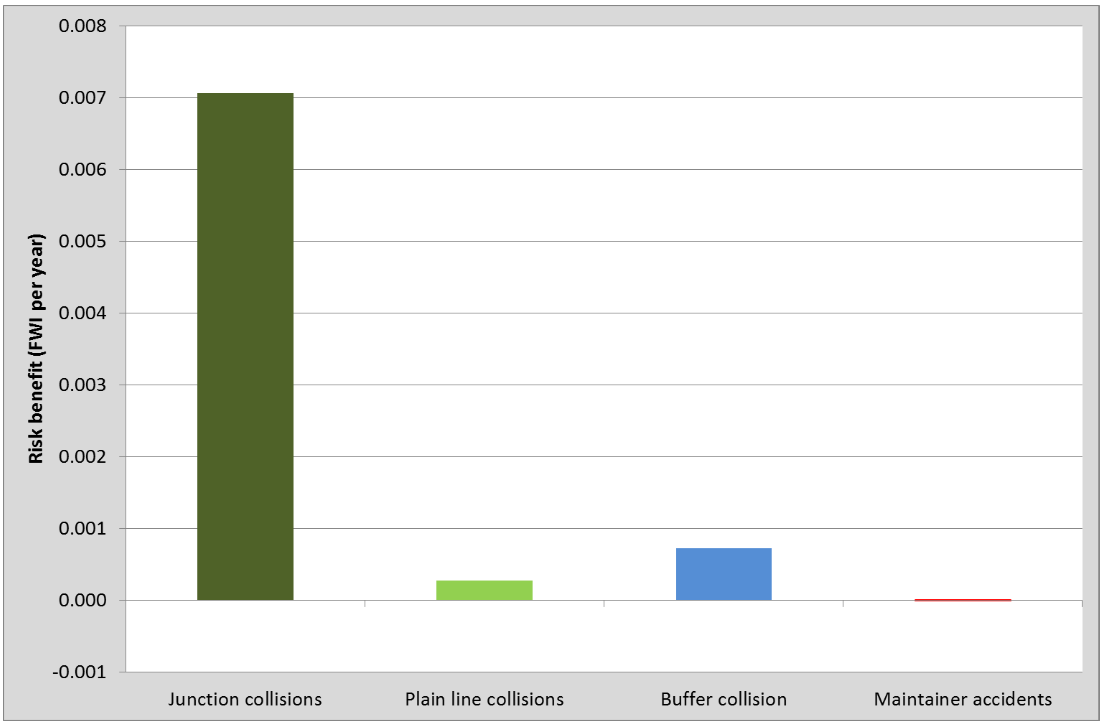


Figure 4 TPWS enhancements from Plan B compared to increased maintainer risk



From Table 3, the following inferences can be made:

- Of the hazards assessed, train-train collision is the dominant risk contributor, comprising nearly 86% of the risk. Buffer collision is the second most significant at 12.9% of the risk, derailment due to overspeeding is approximately 0.7% of the risk and the risk from the maintenance of TPWS units is approximately 0.2% of the risk (ie, insignificant compared with the other hazards).

- Operating temporarily with Crossrail trains that are not ATP fitted and no additional TPWS enhancements results in a significant risk increase over the April 2018 case (of 30%). The most significant area of risk increase is in relation to junction collisions. Note there are some junction signals that are not currently TPWS fitted as only ATP fitted trains currently operate past them.

- Implementing the enhanced TPWS fitment at plain line, some junctions and at buffer approaches has the effect of significantly reducing the risk; overall there is a risk decrease from the base case (April 2018) of approximately 16%. It should be noted that there is an increase in train services of about 8% (considering both the main and relief lines) through the route sections due to the additional Crossrail services. The main contributors to the risk reduction is the enhanced fitment of TPWS at junction signals which benefits all services and is not limited to Crossrail trains (unlike ETCS fitment). There is modest benefit for buffer stop collisions and plain line collisions (see Figure 3).

  Placing additional TPWS OSS on the approaches to buffers results is a relatively small risk reduction and the additional costs of the TPWS units is likely to be grossly disproportionate to the safety benefit achieved for the limited operational life of approximately two years. The resultant increase in risk to track workers from maintaining the equipment is however negligible compared with the benefit. This is shown in Figure 4. There is also a very low installation risk, which is shown in Table 3.

The results in Annex A provide the risk at each signal from train-train collisions. It should be noted that the risk per signal is highly dependent on the timetable being assessed. However, if can be used to make inferences regarding particular signals or signal groups. The following inferences can be made:

- The risk at plain line signals is a small contribution to the overall level of risk and therefore additional TPWS provision is most effectively deployed at junction signals.

- There are some signals, on the airport lines, that are only currently approached by ATP fitted trains, therefore, if these signals were approached by trains without ATP fitted, they would dominate the risk profile. For such signals, it is not possible with TPWS alone to achieve the same level of safety performance that exists with ATP. An example of such as signal is SN316.

- At certain junction signals that are frequently approached by TPWS fitted trains, significant safety improvement can be achieved by additional TPWS OSS fitment.

- At platform starter signals, TPWS can provide a higher level of safety protection over ATP as ATP is only configured to have a TSS-like function. An example of where this is the case is signal SN29. For ETCS, at platform starter signals, it is assumed that the system is 99% effective in mitigating collisions.

5 ASSUMPTIONS

The following assumptions have been made during the course of the risk assessment:

1. **TPWS effectiveness:** The maximum effectiveness of TPWS in reducing the risk from collision and derailment is 95% for Mk1 units. For the Mk3 units the maximum effectiveness is 96.9% and for the Mk4 units the maximum is 98.9%. The values for the Mk3 and Mk4 effectiveness are based upon research conducted for RSSB into reset and continue risk.

2. **TPWS effectiveness:** The TPWS effectiveness calculator, developed by RSSB, provides a reasonable indication of the performance of TPWS in mitigating the risk from train-train collisions. No account is given to the potential upgrade to the trainborne TPWS units.

3. **Routing of trains through Paddington:** The timetable simplifier, developed by Network Rail (ref. SX 0700-19—for ETCS, v0.3), provides a reasonable approximation of the routing of trains between the platforms at Paddington and the Heathrow Airport junction.

4. **Trains approaching buffers on the network:** The Safety Risk Model (SRM) provides a reasonable estimation of the level of risk from train accidents, and application of suitable normalisers can be used to assess a baseline level of risk for Paddington.

5. **Train loading:** The average number of passengers on a train across the network is approximately 100 based upon ORR statistics; the figure is significantly higher at Paddington due the station being a busy terminal station. Based upon station usage values from ORR and the simplified timetable analysis, the typical level of train loading at Paddington is 176.

6. **The likelihood of SPADs:** Data over the past ten years at Paddington (historic SPAD performance) represents a reasonable reflection of future performance in the likelihood of a SPAD per signal approached (for plain line and junction signals).

7. **ATP effectiveness at platform starter signals:** For platform starter signals, ATP at Paddington does not provide speed monitoring, only a train stop function. The effectiveness has been assumed to be the same as the TPWS TSS functionality, based upon the TPWS effectiveness calculator developed by RSSB. For the purposes of the assessment, it is assumed that ATP trains have a two second brake build-up time and an emergency brake effectiveness of 10%g.

8. **ETCS effectiveness at platform starter signals:** For ETCS, at platform starter signals, it is assumed that the system is 99%

effective in mitigating collision risk.

9. **Track Maintainer Exposure:** It is assumed that personnel involved in the maintenance and inspection of TPWS equipment are exposed to typical levels of track worker risk as modelled in RSSB's SRM v8 on a per hour basis. The same assumption is made for any necessary construction work.

10. **Uprate underlying SPAD Rate to account for ATP prevented SPADs**: Based upon previous work for Chiltern, which compared the SPAD rate for ATP fitted and non-fitted services over the same infrastructure it has been found that ATP fitted services experience a similar SPAD rate to non-fitted services. Hence the same SPAD rate has been applied to each service. ATP is, however, assumed to be 99% effective in mitigating SPAD risk for all signals approached (other than platform starter signals). The effectiveness of TPWS is based upon the TPWS effectiveness calculator, developed by RSSB.

11. **ETCS effectiveness:** ETCS is assumed to be 99% effective in mitigating collision risk.

12. **Determine the collision frequency for each signal:** For both plain line and junction collisions, the vast majority of SPADs do not result in a collision due to a range of factors, such as signal replacement on the confliction route, the effectiveness of train protection systems, train driver mitigating action (applying the brakes to stop in the overlap) and flank protection. These factors can effectively be assessed using the Safety Risk Model (SRM), which analyses the underlying probability of collision per SPAD (separately for junction and plain line signals).

13. **Assessment of line speed and collision speeds:** In the event of a collision, an important factor in assessing the potential consequences is the likely speed of a collision. The likely collision speeds have been assessed by accounting for the typical highest line speed in each route section and accounting for the signal type. The assumption is that a junction collision will occur at three quarters of line speed, plain line collisions will occur at two thirds of line speed.

14. **Assessment of the consequence of collisions:** The likely consequences of a collision were assessed based on RSSB's accident consequence model output which can be used to determine the likely FWI based upon the train type, speed and loading. In order to manage the complexity of the model, a curve was used to fit the output of the ACM and used to apply to each route section accounting for the calculated collision speed (as described above) for each signal type in each route section and the passenger loading in each route section.

This is considered to be an assumption that is balanced between being realistic, but also slightly pessimistic as it gives consequences that are slightly higher than predicted by the SRM.

15. **Timetable:** The model is based upon detailed assessment of the potential timetable in 2018, the assessment analyses the twelve-hour period from 07:00 to 19:00. The twelve hour timetable has been scaled to a full day by multiplying by a factor of 1.38. The 1.38 has been derived from prior research conducted by Sotera on behalf of RSSB and has been verified for this project by assessment of the timetable between Reading and Paddington.

16. **In cab TPWS fitment:** By May 2018, 50% of EMUs travelling in area covered by the scope of the project will have Mk3 TPWS units, the remainder will be Mk1 Fitted. Crossrail services will be fitted with Mk4 units.

17. **Construction risk**: Construction risk for the installation of additional TPWS units presents a similar level of risk to track workers as track maintenance activities per staff hour.

18. **Derailment due to overspeeding**: Within the assessment of derailment due to overspeeding, ETCS is assumed to give the same level of protection as ATP.

19. **ETCS safety performance**: There may be additional safety issues resulting from the implementation of ETCS at a busy terminal station as ETCS has not been proven in such an environment. It is assumed that it can generally provide the same level of performance as ATP, except for trains leaving platforms where ETCS provides an enhanced level of protection.

6 ACRONYMS AND ABBREVIATIONS

Acronym	Description	Comments
ACM	Accident Consequence Model	
ALARP	As Low As Reasonably Practicable	
ATP	Automatic Train Protection	
ETCS	European Train Control System	
FWI	Fatalities and Weighted Injuries	A measure of safety performance where the predicted rate of fatalities and minor and minor injuries are combined into an overall measure of risk.
OSS	(TPWS) Over-speed sensor system	
SPAD	Signal Passed at Danger	
SRM	Safety Risk Model	The rail risk model managed on behalf of the industry by RSSB
	(TPWS) Train Stop System'	
TPWS	Train Protection and Warning System	

7 ANNEX A – COLLISION RISK BY SIGNAL

				Train collision risk FWI/yr				% increase compared to April 2018		
Signal number	**Approaches per day**	**Plain line/Jn**	**Expected SPADs per year**	**April 2018**	**Do Nothing May 2018**	**Plan B May 2018**	**Plan A (ETCS) May 2018**	**Do Nothing May 2018**	**Plan B May 2018**	**Plan A (ETCS) May 2018**
SN316	88	J	0.0285	1.6E-05	9.0E-04	2.1E-05	2.1E-05	5427%	31%	27%
SN292	24	J	0.0078	1.0E-05	2.0E-04	2.2E-05	2.0E-05	1887%	114%	100%
SN284	111	J	0.0360	3.3E-04	3.5E-04	3.5E-04	3.4E-04	5%	5%	4%
SN276	111	J	0.0360	4.1E-04	4.3E-04	4.3E-04	4.3E-04	4%	4%	3%
SN266	111	P	0.0020	2.0E-05	3.1E-05	1.8E-06	2.0E-05	55%	-91%	0%
SN258	111	P	0.0020	1.6E-06	1.8E-06	1.3E-06	1.6E-06	17%	-17%	4%
SN248	111	J	0.0360	2.9E-04	3.1E-04	3.4E-04	3.1E-04	8%	17%	5%
SN244	111	P	0.0020	2.0E-05	3.1E-05	1.8E-06	2.0E-05	55%	-91%	0%
SN238	111	J	0.0360	3.9E-04	4.1E-04	4.1E-04	4.1E-04	4%	4%	4%
SN232	111	J	0.0360	3.4E-04	3.7E-04	3.4E-04	3.5E-04	10%	2%	4%
SN224	111	J	0.0360	3.8E-04	4.2E-04	3.6E-04	3.9E-04	9%	-5%	3%
SN214	111	P	0.0020	1.6E-05	2.5E-05	1.4E-06	1.6E-05	55%	-91%	0%
SN210	111	P	0.0020	2.1E-06	2.6E-06	1.4E-06	2.2E-06	22%	-35%	2%
SN206	111	P	0.0020	4.9E-06	7.2E-06	1.3E-06	5.0E-06	46%	-73%	1%
SN202	111	J	0.0360	2.5E-04	2.6E-04	2.6E-04	2.6E-04	5%	5%	5%
SN192	96	J	0.0311	1.5E-04	1.6E-04	1.6E-04	1.6E-04	9%	9%	8%
SN186	96	J	0.0311	1.7E-04	2.0E-04	1.6E-04	1.8E-04	17%	-6%	7%
SN174	96	J	0.0311	1.5E-04	1.6E-04	1.6E-04	1.6E-04	9%	9%	8%
SN164	96	J	0.0311	3.2E-04	4.4E-04	1.6E-04	3.3E-04	40%	-48%	4%
SN156	96	J	0.0311	2.1E-04	2.6E-04	1.6E-04	2.2E-04	26%	-22%	5%
SN144	96	J	0.0311	1.1E-03	1.7E-03	1.6E-04	1.1E-03	60%	-85%	1%
SN134	96	J	0.0311	1.5E-04	1.6E-04	1.6E-04	1.6E-04	9%	9%	8%
SN114	96	J	0.0311	1.5E-04	1.6E-04	1.6E-04	1.6E-04	9%	9%	8%

				Train collision risk FWI/yr				% increase compared to April 2018		
Signal number	Approaches per day	Plain line/Jn	Expected SPADs per year	April 2018	Do Nothing May 2018	Plan B May 2018	Plan A (ETCS) May 2018	Do Nothing May 2018	Plan B May 2018	Plan A (ETCS) May 2018
SN112	96	J	0.0311	5.8E-05	6.3E-05	6.3E-05	6.3E-05	9%	9%	8%
SN300	64	J	0.0207	1.7E-05	1.7E-05	1.7E-05	1.7E-05	0%	0%	0%
SN280	207	J	0.0671	3.6E-04	3.6E-04	3.0E-04	3.6E-04	0%	-16%	0%
SN270	207	J	0.0671	3.5E-04	3.5E-04	3.0E-04	3.5E-04	0%	-13%	0%
SN254	207	J	0.0671	3.0E-04	3.0E-04	3.0E-04	3.0E-04	0%	0%	0%
SN246	207	P	0.0038	8.0E-06	8.0E-06	1.1E-06	8.0E-06	0%	-86%	0%
SN234	207	P	0.0038	8.0E-06	8.0E-06	1.1E-06	8.0E-06	0%	-86%	0%
SN222	207	P	0.0038	8.0E-06	8.0E-06	1.1E-06	8.0E-06	0%	-86%	0%
SN212	207	P	0.0038	8.0E-06	8.0E-06	1.1E-06	8.0E-06	0%	-86%	0%
SN204	207	J	0.0671	3.0E-04	3.0E-04	3.0E-04	3.0E-04	0%	0%	0%
SN194	207	P	0.0038	8.0E-06	8.0E-06	1.2E-06	8.0E-06	0%	-86%	0%
SN178	207	P	0.0038	5.1E-06	5.1E-06	7.3E-07	5.1E-06	0%	-86%	0%
SN160	207	P	0.0038	5.1E-06	5.1E-06	7.3E-07	5.1E-06	0%	-86%	0%
SN146	207	P	0.0038	5.1E-06	5.1E-06	7.3E-07	5.1E-06	0%	-86%	0%
SN120	207	J	0.0671	1.6E-04	1.6E-04	1.6E-04	1.6E-04	0%	0%	0%
SN106	169	J	0.0548	3.2E-05	3.2E-05	3.2E-05	3.2E-05	0%	0%	0%
SN104	38	J	0.0123	1.5E-05	1.5E-05	1.5E-05	1.5E-05	0%	0%	0%
SN102	17	J	0.0055	4.5E-06	4.5E-06	4.5E-06	4.5E-06	0%	0%	0%
SN86	45	P	0.0008	4.7E-08	4.7E-08	4.7E-08	4.7E-08	0%	0%	0%
SN74	169	J	0.0548	2.1E-05	2.1E-05	2.1E-05	2.1E-05	0%	0%	0%
SN32	11	J	0.0036	2.0E-06	2.0E-06	2.0E-06	2.0E-06	0%	0%	0%
SN30	150	J	0.0486	1.8E-05	1.8E-05	1.8E-05	1.8E-05	0%	0%	0%
SN82	34	P	0.0006	3.9E-08	3.9E-08	3.9E-08	3.9E-08	0%	0%	0%
SN90	96	J	0.0311	5.8E-05	6.3E-05	6.3E-05	6.3E-05	9%	9%	8%
SN78	96	J	0.0311	3.7E-05	4.0E-05	4.0E-05	4.0E-05	9%	9%	8%

Signal number	Approaches per day	Plain line/Jn	Expected SPADs per year	Train collision risk FWI/yr				% increase compared to April 2018		
				April 2018	Do Nothing May 2018	Plan B May 2018	Plan A (ETCS) May 2018	Do Nothing May 2018	Plan B May 2018	Plan A (ETCS) May 2018
SN34	48	J	0.0156	1.9E-05	2.0E-05	2.0E-05	2.0E-05	9%	9%	8%
SN36	48	J	0.0156	1.9E-05	2.0E-05	2.0E-05	2.0E-05	9%	9%	8%
SN84	132	P	0.0024	9.7E-08	9.7E-08	9.7E-08	9.7E-08	0%	0%	0%
SN72	10	J	0.0032	3.7E-06	3.7E-06	3.7E-06	3.7E-06	0%	0%	0%
SN70	45	J	0.0146	7.8E-06	7.8E-06	7.8E-06	7.8E-06	0%	0%	0%
SN28	10	J	0.0032	3.7E-06	3.7E-06	3.7E-06	3.7E-06	0%	0%	0%
SN26	45	J	0.0146	7.8E-06	7.8E-06	7.8E-06	7.8E-06	0%	0%	0%
SN29	12	J	0.0039	1.7E-05	1.2E-06	1.2E-06	1.1E-06	-93%	-93%	-94%
SN25	12	J	0.0039	3.3E-06	1.2E-06	1.2E-06	1.1E-06	-64%	-64%	-66%
SN43	85	J	0.0276	3.6E-05	3.8E-05	3.8E-05	3.7E-05	3%	3%	3%
SN45	8	P	0.0001	3.6E-09	7.7E-09	7.7E-09	7.2E-09	114%	114%	100%
SN47	8	P	0.0001	3.6E-09	7.7E-09	7.7E-09	7.2E-09	114%	114%	100%
SN63	82	J	0.0266	3.6E-05	3.7E-05	3.7E-05	3.7E-05	3%	3%	3%
SN65	8	J	0.0026	9.4E-07	2.0E-06	2.0E-06	1.9E-06	114%	114%	100%
SN67	8	J	0.0026	5.3E-07	1.1E-06	1.1E-06	1.1E-06	114%	114%	100%
SN87	84	J	0.0272	5.6E-05	5.8E-05	5.8E-05	5.8E-05	5%	5%	4%
SN1	17	J	0.0055	1.1E-05	1.1E-05	1.1E-05	1.1E-05	0%	0%	0%
SN3	22	J	0.0071	8.2E-06	8.2E-06	8.2E-06	8.2E-06	0%	0%	0%
SN5	20	J	0.0065	1.2E-05	1.2E-05	1.2E-05	1.2E-05	0%	0%	0%
SN7	25	J	0.0081	6.9E-05	6.9E-05	6.9E-05	6.9E-05	0%	0%	0%
SN9	19	J	0.0062	5.9E-05	5.9E-05	5.9E-05	5.9E-05	0%	0%	0%
SN11	39	J	0.0126	6.1E-05	6.1E-05	6.1E-05	6.1E-05	0%	0%	0%
SN13	32	J	0.0104	2.6E-05	2.6E-05	2.6E-05	2.6E-05	0%	0%	0%
SN15	18	J	0.0058	6.9E-06	6.9E-06	6.9E-06	6.9E-06	0%	0%	0%
SN17	10	J	0.0032	3.8E-05	3.8E-05	3.8E-05	3.8E-05	0%	0%	0%

				Train collision risk FWI/yr				% increase compared to April 2018		
Signal number	Approaches per day	Plain line/Jn	Expected SPADs per year	April 2018	Do Nothing May 2018	Plan B May 2018	Plan A (ETCS) May 2018	Do Nothing May 2018	Plan B May 2018	Plan A (ETCS) May 2018
SN19	17	J	0.0055	2.1E-05	2.1E-05	2.1E-05	2.1E-05	0%	0%	0%
SN41	114	J	0.0370	1.3E-05	1.3E-05	1.3E-05	1.3E-05	0%	0%	0%
SN39	65	J	0.0211	1.0E-05	1.0E-05	1.0E-05	1.0E-05	0%	0%	0%
SN37	42	J	0.0136	8.2E-06	8.2E-06	8.2E-06	8.2E-06	0%	0%	0%
SN61	3	J	0.0010	3.5E-07	3.5E-07	3.5E-07	3.5E-07	0%	0%	0%
SN59	179	J	0.0580	2.4E-05	2.4E-05	2.4E-05	2.4E-05	0%	0%	0%
SN57	39	J	0.0126	7.8E-06	7.8E-06	7.8E-06	7.8E-06	0%	0%	0%
SN89	14	J	0.0045	3.7E-06	6.2E-06	6.2E-06	5.9E-06	68%	68%	60%
SN85	3	P	0.0001	2.1E-09	2.1E-09	2.1E-09	2.1E-09	0%	0%	0%
SN83	179	J	0.0580	5.3E-05	5.3E-05	5.3E-05	5.3E-05	0%	0%	0%
SN81	42	J	0.0136	1.8E-05	1.8E-05	1.8E-05	1.8E-05	0%	0%	0%
SN117	7	J	0.0023	1.3E-06	1.3E-06	1.3E-06	1.3E-06	0%	0%	0%
SN111	98	J	0.0318	6.2E-05	6.7E-05	6.7E-05	6.6E-05	8%	8%	7%
SN123	98	J	0.0318	8.6E-05	1.1E-04	6.5E-05	9.0E-05	26%	-24%	5%
SN127	98	J	0.0318	2.0E-04	2.3E-04	1.1E-04	2.2E-04	15%	-48%	6%
SN137	98	J	0.0318	4.0E-04	5.4E-04	2.2E-04	4.1E-04	36%	-46%	3%
SN153	96	J	0.0311	3.9E-04	5.6E-04	1.8E-04	4.1E-04	43%	-53%	3%
SN163	96	J	0.0311	4.0E-04	5.7E-04	1.8E-04	4.1E-04	43%	-53%	3%
SN175	96	J	0.0311	1.5E-04	1.6E-04	1.6E-04	1.6E-04	9%	9%	8%
SN187	96	P	0.0018	1.1E-06	1.6E-06	6.2E-07	1.2E-06	38%	-45%	4%
SN199	114	J	0.0370	4.9E-04	5.1E-04	4.8E-04	5.0E-04	4%	-2%	3%
SN203	114	P	0.0021	1.3E-06	1.4E-06	1.4E-06	1.4E-06	5%	5%	4%
SN209	114	P	0.0021	2.1E-05	3.2E-05	1.8E-06	2.1E-05	53%	-91%	0%
SN211	114	P	0.0021	1.9E-06	2.0E-06	1.7E-06	1.9E-06	9%	-10%	3%
SN215	114	J	0.0370	7.6E-04	9.3E-04	4.7E-04	7.8E-04	22%	-39%	2%

				Train collision risk FWI/yr				% increase compared to April 2018		
Signal number	**Approaches per day**	**Plain line/Jn**	**Expected SPADs per year**	**April 2018**	**Do Nothing May 2018**	**Plan B May 2018**	**Plan A (ETCS) May 2018**	**Do Nothing May 2018**	**Plan B May 2018**	**Plan A (ETCS) May 2018**
SN225	114	J	0.0370	4.6E-04	5.2E-04	3.7E-04	4.7E-04	13%	-19%	2%
SN233	114	J	0.0370	5.1E-04	5.9E-04	3.7E-04	5.2E-04	16%	-27%	2%
SN239	114	P	0.0021	2.9E-06	3.5E-06	1.8E-06	2.9E-06	22%	-38%	2%
SN243	114	J	0.0370	3.7E-04	4.0E-04	2.9E-04	3.8E-04	10%	-20%	4%
SN253	114	P	0.0021	1.6E-05	2.5E-05	1.3E-06	1.6E-05	53%	-92%	0%
SN265	114	J	0.0370	5.2E-04	5.8E-04	4.8E-04	5.4E-04	10%	-8%	3%
SN273	114	P	0.0021	2.1E-05	3.2E-05	1.6E-06	2.1E-05	53%	-92%	0%
SN283	114	J	0.0370	3.9E-04	4.1E-04	4.1E-04	4.1E-04	4%	4%	4%
SN287	114	J	0.0370	6.0E-04	6.8E-04	4.8E-04	6.2E-04	13%	-20%	2%
SN303	96	J	0.0311	4.4E-04	6.3E-04	2.1E-04	4.6E-04	43%	-53%	3%
SN323	24	J	0.0078	4.4E-06	8.9E-04	9.5E-06	8.9E-06	19900%	114%	100%
SN105	35	J	0.0113	1.3E-05	1.3E-05	1.3E-05	1.3E-05	0%	0%	0%
SN107	179	J	0.0580	5.7E-05	5.7E-05	5.7E-05	5.7E-05	0%	0%	0%
SN109	10	J	0.0032	1.8E-06	1.8E-06	1.8E-06	1.8E-06	0%	0%	0%
SN125	207	J	0.0671	6.8E-05	6.8E-05	6.8E-05	6.8E-05	0%	0%	0%
SN135	207	P	0.0038	9.9E-07	9.9E-07	4.1E-07	9.9E-07	0%	-59%	0%
SN151	207	P	0.0038	5.1E-06	5.1E-06	7.3E-07	5.1E-06	0%	-86%	0%
SN159	207	P	0.0038	5.1E-06	5.1E-06	7.3E-07	5.1E-06	0%	-86%	0%
SN173	207	P	0.0038	5.1E-06	5.1E-06	7.3E-07	5.1E-06	0%	-86%	0%
SN179	207	P	0.0038	5.1E-06	5.1E-06	7.3E-07	5.1E-06	0%	-86%	0%
SN191	207	P	0.0038	8.0E-06	8.0E-06	1.1E-06	8.0E-06	0%	-86%	0%
SN201	207	J	0.0671	3.1E-04	3.1E-04	3.0E-04	3.1E-04	0%	-2%	0%
SN207	207	P	0.0038	8.0E-06	8.0E-06	1.1E-06	8.0E-06	0%	-86%	0%
SN213	207	P	0.0038	8.0E-06	8.0E-06	1.1E-06	8.0E-06	0%	-86%	0%
SN231	207	P	0.0038	8.0E-06	8.0E-06	1.1E-06	8.0E-06	0%	-86%	0%

				Train collision risk FWI/yr				% increase compared to April 2018		
Signal number	**Approaches per day**	**Plain line/Jn**	**Expected SPADs per year**	**April 2018**	**Do Nothing May 2018**	**Plan B May 2018**	**Plan A (ETCS) May 2018**	**Do Nothing May 2018**	**Plan B May 2018**	**Plan A (ETCS) May 2018**
SN237	207	P	0.0038	8.0E-06	8.0E-06	1.1E-06	8.0E-06	0%	-86%	0%
SN249	207	J	0.0671	3.0E-04	3.0E-04	3.0E-04	3.0E-04	0%	0%	0%
SN255	207	J	0.0671	3.0E-04	3.0E-04	3.0E-04	3.0E-04	0%	0%	0%
SN271	207	J	0.0671	3.3E-04	3.3E-04	3.0E-04	3.3E-04	0%	-8%	0%
SN285	207	J	0.0671	3.0E-04	3.0E-04	3.0E-04	3.0E-04	0%	0%	0%
SN319	64	P	0.0012	1.0E-07	1.0E-07	1.0E-07	1.0E-07	0%	0%	0%
SN321	64	J	0.0207	1.2E-05	1.2E-05	1.2E-05	1.2E-05	0%	0%	0%