19-005

Quantification of factors affecting emergency protection rules

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Introduction

RSSB standards project 19-005 Objective 3 is *to review the arrangements associated with emergency protection including the use of detonators*.

The hazards addressed by the present rules are almost entirely of a secondary accident where another line has become obstructed or unsafe for a train to pass, published in GERT8000-M1 *Dealing with a train accident or train evacuation,* or when a driver observes a hazard to trains on another line, published in GERT8000-TW1 *Preparation and movement of trains.*

Actions are prescribed, primarily for a driver to inform the signaller about the hazard and to take actions before it has been protected. GERT8000-M1 was last fully reviewed in 1999 and at that stage recognised that an emergency radio call would be the quickest way to inform the signaller (although through Operations Control where national radio network (NRN) radio was in use). This pre-dated the availability of GSM-R and the railway emergency group call (REC) facility. More recently in 2020 the driver's actions were altered to state that a REC must be attempted, before establishing whether any other line is obstructed rather than the reverse. Some changes in recent years have been intended to align the instructions in GERT8000-TW1 with those in GERT8000-M1.

In progressing this objective, no proposals have been made that assume any enhancements to means of secondary communications beyond what already exists.

During this review several questions have arisen and this document outlines the rationale for how each of these questions should be addressed.

The questions are:

1. In what order should communication methods be attempted?
2. What is the benefit of detonators to protect a second direction?
3. What is the benefit of detonators at tunnels and junctions and what should the driver do at these locations?
4. What use should be made of track circuit operating clips (TCOCs)?
5. What is the potential for errors or inefficiencies protecting trains?
6. How do detonators compare to hand signalling to stop trains?

Communication method order

Following a train accident there are several steps that a driver can take to communicate to other drivers the need to stop their trains. The primary method is the GSM-R emergency call (REC) from the driving cab radio. Having attempted this, other means of communication can then be attempted. The order in which these means of communication are attempted can have a large impact on the probability of stopping any approaching trains.

RSSB developed the Secondary Communication Risk Model (Details of the model are available in the appendix and on the RSSB website: Driver-signaller communication and train protection modelling) in order to identify the optimal means of secondary communication and the optimal sequencing of communication actions.

The secondary communications risk modelling found that the optimal order in which to attempt different communication and protection actions is

1. Main cab GSM-R radio
2. Any other method available in main cab (alternative networks and devices)
3. The GSM-R cab radio in an alternative cab on the train
4. TCOC placement
5. Any other method of communication available lineside whilst displaying a hand danger signal to any approaching trains

This is the sequence of actions which if applied following all train accidents would result in the lowest possible level of secondary collision risk on average. It is not the best sequence of actions in all potential train accidents but is the best on average.

We propose that defining a single course of actions to be applied in all circumstances is overall safer than providing a complex decision tree requiring consideration of all the different aspects of a train accident such as:

- Linespeed and headway
- Visibility – track curvature and lineside structures, mist and fog, light levels
- The number of adjacent tracks and fouled tracks
- Braking capacity of approaching trains and any adhesion impacting factors

Such a decision tree would both delay a driver's actions, increase uncertainty and increase the chance that vital actions are missed.

Protecting a second direction

A potential benefit of detonators is that they can be left on the track to provide a warning signal to approaching trains whilst the driver goes away to protect from trains in another direction. This allows for a chance to stop trains in multiple directions which would not be available otherwise if other methods of communication had failed.

Following a train accident

For there to be a second direction needing protection following a train accident, at least two tracks must be fouled (not including the track the train was occupying). 1 track in the opposite direction and 1 track in the same direction that the train(s) involved in the accident were not travelling on. Tracks occupied by trains involved in the accident will be protected either by absolute block controls, axle counter occupancy or by the placement of TCOCs (in track-circuited areas).

For there to be sufficient time for a driver to provide protection in two directions there needs to be enough time for the driver to walk at least 4 km. that is 2km in one direction, back to the train and then at least braking distance in the second direction. This could easily require at least 60 minutes.

A simple pessimistic estimate of the probability that this might be required following a train accident is:

Probability of communication failure

X Probability of derailing sufficiently to foul multiple other lines

X Probability of there being multiple adjacent tracks and sufficient time to protect the second direction

Probability of communication failure is estimated as 1.65% composed from:

- 1 in 913 probability of GSM-R network failure (derived from GSM-R failures data for communication model)
- 3.2% probability that all train radios are failed or inaccessible. This is the pessimistically rounded up product of two probabilities derived through review of RAIB reports (appendix)
  - 8% probability of driving cab radio failed or inaccessible
  - 40% probability of all train radios failed or inaccessible IF driving cab radio is failed or inaccessible
  - Giving 8% x 40% = 3.2%

(If the next train accident resulted in a train with all radios damaged this value would increase to 4.7%, this is approximately a 50% increase)

- 50% probability all secondary comms methods fail (estimate of current availability of lineside phones)

Probability of the train derailing sufficiently to obstruct multiple other lines, given that there are multiple lines to obstruct, is estimated as 10% (pessimistic interpretation of review of past events).

Probability that there are at least 3 tracks at the accident location and at least 60 minutes between trains is taken from CCT analysis as 0.08%.

Together this gives an estimate that there is a less than 1 in 750,000 probability of needing to and having the time to protect a second direction following a train accident.

An additional consideration is that for events where cab radios are damaged it is more likely that the driver is incapacitated in some way meaning that they would not be available to walk out to undertake protection making this even more unlikely to happen.

A risk estimate in Fatalities and Weighted Injuries (FWI) can be made from this probability:

	12 events per year	The number of train accidents which could foul an adjacent line (from SMIS data).
X	7.1FWI per event	The average additional risk per secondary collision (from RSSB Safety Risk Model data)
X	1/750000	probability of needing to and having the time to protect a second direction following a train accident
=	0.00011 FWI per year.	

Following sighting of a hazard to other trains

A similar argument can be made for needing to protect the track following the sighting of a hazard to other trains. In this case there is a significantly smaller risk of the driving cab radio being failed as there is no initial train accident to damage the radio.

- 1 in 913 probability of GSM-R network failure
- 50% probability all secondary comms methods fail (estimate of current availability of lineside phones)
- Probability that there are at least 3 tracks at the accident location and at least 60 minutes between trains is taken from CCT analysis as 0.08%.

Together this gives that there is less than a 1 in 2,280,000 probability of needing to and having the time to protect a second direction following the sighting of a hazard to other trains.

An interim result from the secondary communication risk model is that there is around 0.13 FWI per year of collision with object or person risk which could be avoided through a driver sighting the hazard on an adjacent line and protecting it.

This gives a total of 1 in 17,000,000 FWI per year of benefit from the train driver being able to place detonators and walk to protect a second direction.

Protecting tunnels and junctions

Another potential benefit of detonators is that they can be left on the track to provide a warning signal to approaching trains at junctions or tunnel portals whilst the driver proceeds along one route or through a separate tunnel bore. This allows for a chance to stop trains on the other route or in an alternative tunnel bore which would not be available otherwise if other methods of communication had failed.

A simple pessimistic estimate of the probability that this might be required can be calculated as for second direction protection.

Probability of communication failure is estimated as 1.65% using the same derivation as in the previous section.

Probability of encountering a junction or tunnel portal before encountering an approaching train whilst walking out given that all prior communication attempts have failed (from CCT analysis, appendix)

- 2.08% probability of encountering a junction
- 0.42% probability of encountering a tunnel portal

Together this gives an estimate that there is a

- 0.034% probability of encountering a junction (about 1 in 2,900 events)
- 0.007% probability of encountering a tunnel portal (about 1 in 14,500 events)

Assuming 300m of viewing distance for a hand danger signal and 9%g braking capacity, the CCT analysis calculates that 44.5% of approaching trains would have sufficient braking distance to stop from sighting the hand danger signal displayed at the junction. This gives

- 0.019% probability of encountering a junction and not being able to stop the next train before the train accident site with a hand danger signal due to insufficient braking distance (about 1 in 5,200 events)

- 0.004% probability of encountering a tunnel portal and not being able to stop the next train before the train accident site with a hand danger signal due to insufficient braking distance (about 1 in 26,100 events)

The chance of the driver continuing from the junction along the route on which the next train is not approaching is conservatively estimated to be 50%. This is because the driver will have some route knowledge potentially allowing them to have a better than random knowledge of where the next train is more likely to approach from.

Use of TCOCs

The secondary communication risk model suggested that the time spent to place is not always efficient as

- TCOCs are not effective in non-track-circuited areas
- It requires there to be a protecting signal that the TCOC can set to danger ahead of the approaching train and that it is located to allow sufficient braking distance
- Takes time which could be used communicating

The communication modelling shows TCOCs average impact is

- Negative with FLT secondary communication
- And positive with other forms of secondary communication

The modelling also finds that the optimal time for the placement of TCOCs is immediately after leaving the driving cab before going to attempt communication form an alternative cab.

There are many edge cases where these conclusions vary but these findings hold on average across all train operations.

Potential for errors

Review of RAIB incident reports and the available SMIS data has not identified any events where train drivers did not follow the current train protection rules correctly.

Several events were identified where train drivers did not follow the most efficient sequence of train protection actions. They were correctly following the rules at the time, but the rules are not explicit as to the optimal sequence of actions.

Bromsgrove 2020	REC delayed as driver checking train, the correct action according to the rulebook at the time. This has already been addressed in rules changes to make the REC first. Collision may have been avoided if REC had been made immediately.
Godmersham 2015	Rear cab radio was working but not attempted, TCOCs were not placed. Thankfully no escalation of the event occurred but approaching trains may have been stopped more quickly.
Lavington 2010	No attempt was made to use the rear cab radio, a signal post telephone was missed on walk to place detonators and no phone number was available to driver or driver travelling as passenger for controlling signaller so they contacted control instead.

Refining the rules to explicitly state the optimal sequence of actions to take in the event of a train accident will help to ensure that approaching trains are stopped as efficiently as possible in future.

It is also expected that reducing the complexity of the rules will additionally reduce the likelihood of errors occurring.

Detonators and hand signals

There are several points to consider when comparing the relative effectiveness of using detonators and hand signals. The table gives points of consideration for each method:

Detonators	Hand danger signal
• Work at a single point and rely on the driver hearing them. To stop a train before it reaches the point of an incident, they must be placed with sufficient braking distance. • There is some evidence that they can be hard to hear in a modern driving cab and therefore may not be fully effective. • Can be left on the line thereby allowing for protection of multiple directions albeit with increasing amounts of time required to protect each additional direction.	• Can work at a distance: the driver doesn't have to get to braking distance to stop the approaching train in time so long as the approaching train can see the hand danger signal being given in sufficient time. • A high-visibility jacket and flag or lamp on or about the track in front of a train is potentially more visually attention grabbing than detonators are audibly attention grabbing • Review of incidents in SMIS did not identify evidence of a driver not seeing a hand signal. • Requires continual human presence and therefore a driver could only protect one direction in this way.

Summary

It would be beneficial to change the focus of the train protection rules to prioritisation of communication via Railway Emergency Call (REC) and with the signaller.

Emphasis should be put on the use of GSM-R radios in alternative train cabs due to the modelled safety benefit from their use.

Rules should be agnostic to the means of secondary communication so that they do not need to be updated as secondary comms provision changes.

Whichever solutions are in use or planned to be put in use, all workforce involved (driver, guard, competent person, signaller, etc) should be appropriately briefed and trained in the process, and appropriate support materials should be developed. These could be in the form of briefing notes, videos, training sessions, or rule book additions. Staff need to be fully trained and competent in the given solution to reduce the risk of errors that could affect safety.

Communication sequencing

Rules should highlight the most effective order in which to attempt different communication methods as modelled.

- Main cab GSM-R radio
- Other means available in cab (alternative networks and devices)
- The GSM-R cab radio in an alternative cab on the train

TCOCs

The modelling finds that the optimal time for the placement of TCOCs is immediately after leaving the driving cab before going to attempt communication form an alternative cab, the rules should emphasise this.

TCOC use should be maintained in the rules to avoid all the potential disruption and confusion involved in removing them from use and then reintroducing them as secondary communication methods change.

Detonators

Detonators only provide a very small benefit in a minority of events where all other communication has failed. We expect that this will only become more unlikely as other means of communication increase in reliability.

Removal of detonators from the rules allows for considerable simplification which will in turn allow the rules to be more easily and consistently applied.

Appendix

RAIB reports

RAIBs Investigation reports for heavy rail freight and passenger train collisions, derailments and striking of objects back to 2013 were reviewed. Low speed platform events and events in possessions were excluded from consideration due to the differences in consequences and subsequent need for train protection.

The reports detail in depth investigation of the sequence of events involved in a train accident and their causes together with recommendations to industry. Review of these documents was undertaken for details of what communication and protection steps were taken and in what order and any damages to drivers or communication equipment which could inform the rationale for train protection rules.

RAIB reports are available online at Rail Accident Investigation Branch reports - GOV.UK

RAIB report review conclusions

54 investigation reports were reviewed, involving 63 trains. There were 9 train-train collisions, 30 derailments, 14 trains striking landslips or road vehicles and 1 track washout under the train.

In these 54 events the driving cab radio was rendered inaccessible or inoperable for 5 of the 63 (8%) trains involved. The driving cab radios in two further trains were damaged such that they could still initiate a Radio Emergency Call (REC) but the driver received no indication that the REC had been successful. The 5 events were;

- Carmont (cab inaccessible and driver fatality),
- Broughty Ferry (train struck tree, radio inaccessible),
- Grange-over-Sands (radio damaged)
- Godmersham (radio damaged)
- Salisbury tunnel Junction (radio damaged in one of the two trains involved).

Of the 5 trains with damaged or inaccessible driving cab radios, alternative cab radios were rendered inaccessible or inoperable for 2 of the 5 (40%) trains with damaged or inaccessible driving cab radios. The two events were

- Carmont, where the rear cab had stopped next to the leading power car which was on fire and the RAIB report suggests this made it unsafe to use.
- Salisbury tunnel junction where a REC was attempted from the rear cab in one train but failed

Of the 5 trains with a damaged or inaccessible driving cab there was one train where the alternative cab radio was working but the train driver did not attempt to use it.

A mobile device was used to communicate with the signaller in 6 of the 54 (11%) events, 4 of these instances being driver or guard mobile device use and 2 being driver or guard travelling as a passenger.

Signallers were alerted to a problem by indicators or alerts in the signal centre before any contact was made with them through other means in 6 out of 54 events.

RAIB investigation reports summary of communication detail

Location	Date	event type	Cab radio	Alternative Cab radio	Other comms	Detonators or hand signal?	Report link
Castle Donnington	21/01/2013	Derailment	Not mentioned		Signaller alerted by alarm/indicators		R022014_140116_Castle_Donington.pdf
Ordsall Lane Junction	23/01/2013	Derailment	Working and used		SPT used by another trains driver TCOCs placed		R072014_140331_Ordsall_Lane_Junction.pdf
Liverpool Street Station	23/01/2013	Derailment	Not mentioned				R272014_141211_Liverpool_Street.pdf
Athelney	21/03/2013	Collision with object	Working and used				R042014_140224_Athelney.pdf
Jetty Avenue level crossing	14/07/2013	Collision with object	Working and used				R282014_141215_Jetty_Avenue_UWC.pdf
Buttington Hall level crossing	16/07/2013	Collision with object	Working and used				R062014_140327_Buttington_Hall_V2.pdf
Stoke Lane level crossing	27/08/2013	Derailment	Working and used				R022015_150402_Stoke_Lane.pdf

Location	Date	event type	Cab radio	Alternative Cab radio	Other comms	Detonators or hand signal?	Report link
Primrose Hill / Camden Road West Junction	15/10/2013	Derailment	Not mentioned				R212014_141014_Camden_Road_West_Jn.pdf
Gloucester	15/10/2013	Derailment	Signaller contacted driver				R202014_141009_Gloucester.pdf
Bridgewater level crossing	16/01/2014	Collision between trains	Working and used				R252014_141120_Bridgeway.pdf
Angerstein Junction	02/04/2014	Derailment	Working and used		Driver mobile device		R112015_150812_Angerstein_Junction.pdf
Frampton level crossing	11/05/2014	Collision with object	Working and used		Crossing phone available but unused		R052015_150528_Frampton_LC.pdf
Paddington	25/05/2014	Derailment	Not mentioned				R032015_150430_Paddington.pdf
Porthkerry	02/10/2014	Derailment	Working and used		Signaller alerted by alarm/indicators		R102015_150806_Porthkerry.pdf

Location	Date	event type	Cab radio	Alternative Cab radio	Other comms	Detonators or hand signal?	Report link
Heworth	23/10/2014	Derailment	Not mentioned		Signaller alerted by alarm/indicators		R162015_150924_Heworth.pdf
Newbury	17/11/2014	Collision with object	Working and used				R152015_150923_Newbury.pdf
Froxfield	22/02/2015	Collision with object	Working and used				R022016_160120_Froxfield.pdf
Washwood Heath West Junction	23/03/2015	Derailment	Not mentioned		Signaller alerted by alarm/indicators		R012016_160111_Washwood_Heath.pdf
Oakwood Farm level crossing	14/05/2015	Collision with object	Working and used				R072016_160428_Oakwood_Farm.pdf
Angerstein junction	03/06/2015	Derailment	Signaller contacted driver		Signaller alerted by alarm/indicators		R102016_160601_Angerstein_Junction.pdf
Langworth	30/06/2015	Derailment	Assumed working as comms mentioned		Signaller alerted by alarm/indicators		R112016_160627_Langworth.pdf

Location	Date	event type	Cab radio	Alternative Cab radio	Other comms	Detonators or hand signal?	Report link
Godmersham	26/07/2015	Derailment	Damaged in incident	Working but not used	Travelling driver mobile device to control TCOCs not used but would have been effective	Hand signal - driver reached oncoming train that signaller had already stopped	R052016_160406_Godmersham..pdf
Knaresborough	07/11/2015	Derailment	Working and used				R162016_160804_Knaresborough.pdf
Barrow-upon-Soar	14/02/2016	Collision between trains	Working and used				R212016_161027_Barrow_upon_Soar.pdf
Hockham Road level crossing	10/04/2016	Collision with object	REC successful but driver unaware due to damage		Guard mobile device Crossing telephone		R042017_170314_Hockham_Road.pdf
Watford	16/09/2016	Derailment and collision	Working and used			Train hazard warning lights	R112017_170810_Watford.pdf
Lewisham	24/01/2017	Derailment	Working and used				180228_R042018_Lewisham.pdf

Location	Date	event type	Cab radio	Alternative Cab radio	Other comms	Detonators or hand signal?	Report link
East Somerset Junction	20/03/2017	Derailment	Working and used				R192017_171213_East_Somerset_Junction.pdf
Ely West Junction	14/08/2017	Derailment	Working and used				R092018_180802_Ely_West_Junction.pdf
Waterloo	15/08/2017	Collision between trains	Working and used				Collision at London Waterloo, 15 August 2017
Frognal Farm level crossing	23/10/2017	Collision with object	Working and used				R122018_180823_Frognal_Farm.pdf
Stainforth Road level crossing	11/01/2018	Collision with object	Working and used				R082018_180719_Stainforth_Road.pdf
Loch Elit	22/01/2018	derailment	Working and used				R102018_180807_Loch_Eilt.pdf
Willesden High Level Junciton	06/05/2019	Derailment	No comms as driver unaware at time of event				Freight train derailment at Willesden High Level Junction, north-west London, 6 May 2019
Corby	13/06/2019	Collision with object	Working and used				Train collision with material washed out from a cutting slope at Corby, Northamptonshire

Location	Date	event type	Cab radio	Alternative Cab radio	Other comms	Detonators or hand signal?	Report link
Neville Hill	13/11/2019	Collision between trains	Working and used				Collision and derailment at Neville Hill, 13 November 2019
Wanstead Park	23/01/2020	Derailment	Working and used				Derailment of a freight train near Wanstead Park, London, 23 January 2020
Eastleigh	28/01/2020	Derailment	Working and used				R022021_210304_Eastleigh.pdf
Bromsgrove	23/03/2020	Collision between trains	Working and used. But REC delayed as rules at time said to check train first				Passenger train collision with a derailed locomotive at Bromsgrove, 23 March 2020
Carmont	12/08/2020	Derailment	Driver fatality, cab inaccessible	Inaccessible	Infrastructure worker mobile to 999 Conductor as passenger mobile call to 999. FLT after 1.7km walk (~40 mins)		R022022_220310_Carmont.pdf

Location	Date	event type	Cab radio	Alternative Cab radio	Other comms	Detonators or hand signal?	Report link
Llangennach	26/08/2020	Derailment	Working and used				Derailment and fire involving a tanker train at Llangennech, Carmarthenshire, 26 August 2020
Sheffield Station	11/11/2020	Derailment	Signaller contacted driver				Freight train derailment at Sheffield station, 11 November 2020
Dalwhinnie	10/04/2021	Derailment	Working and used	Not mentioned			Wrong side signalling failure and derailment at Dalwhinnie, Badenoch and Strathspey, 10 April 2021
Kisby level crossing	19/08/2021	Collision with object	REC successful but driver unaware due to damage	Not mentioned	SPT used	Not mentioned	Collision between a train and agricultural equipment at Kisby user worked crossing, Cambridgeshire, 19 August 2021
Challow	21/10/2021	Collision between trains	Assumed working as comms mentioned	Not mentioned			Collision between a passenger train and a hand trolley at Challow, Oxfordshire, 21 October 2021
Salisbury Tunnel Junction	31/10/2021	Collision between trains	Damaged in one train. Working and used in other train	Attempted but didn't work in one train	Mobile device to emergency services	Not mentioned	R122023_231024_Salisbury.pdf

Location	Date	event type	Cab radio	Alternative Cab radio	Other comms	Detonators or hand signal?	Report link
London Gateway	24/12/2021	derailment	Working and used	Not mentioned			R142023_231219_London_Gateway.pdf
Haddiscoe	30/01/2022	Washout under train	Working and used				R072023_230727_Haddiscoe.pdf
Loversall Carr Junction	05/07/2022	Collision between trains	Working and used	Not mentioned			Collision between two freight trains at Loversall Carr Junction, Doncaster 5 July 2022
Petteril Bridge	19/10/2022	Derailment	Assumed working as comms mentioned	Not mentioned	Not mentioned	Not mentioned	R102023_231010_Petteril_Bridge_Junction.pdf
Yarnton near Hanborough	10/02/2023	Collision with object	Working and used	Not mentioned			R012024_240201_Yarnton.pdf
Broughty Ferry	27/12/2023	Collision with object	Working but inaccessible	Possible conductor REC - unclear	Driver mobile device	Not mentioned	R132024_241223_Broughty_Ferry.pdf
Roudham Heath	06/02/2024	Derailment	Working and used	Not mentioned			R032025_250203_Roudham_Heath.pdf
Grange-over-Sands	22/03/2024	Derailment	Damaged in incident	Working and used	Not mentioned		R022025_250128_Grange-over-Sands.pdf

Common Consequence Tool 25m section data

The Common Consequence Tool (CCT) provides a method for estimating the potential safety consequences (fatalities and injuries to train occupants) arising from a train derailment, independent of the cause of derailment. Part of this tool includes data on each 25m section of track on the GB mainline rail network including number of adjacent tracks, train frequency, train type and linespeed.

These values were used to estimate

1. The likelihood that a driver would be able to walk a given distance from the train accident site before encountering an approaching train. And therefore, their likelihood of reaching a junction or tunnel before encountering an approaching train.

   Assuming on average that

   - there is a junction per 10 route kilometres (calculation of distance to next junction using RSSB T1316 track model and CCT train movements data estimates that any given train movement is on average 12.295km from the next junction – 10km is used as a conservative simplification.
   - there is a tunnel every 50 route kilometres
   - train accidents are randomly distributed proportionally to train movements
   - drivers would spend 5 minutes attempting communications from the train cabs
   - then would walk forwards at 1m/s

   We calculate that a driver

   - would reach a junction before encountering an oncoming train in <2.08% of train accidents.
   - would reach a tunnel portal before encountering an oncoming train in <0.48% of train accidents.

   It is expected that these values are conservative as there tend to be more junctions where there are more train movements and so time between trains is likely to be lower on average around junctions meaning that drivers would have less chance of walking out to a junction before encountering an oncoming train.

2. These values can be further refined to estimate the proportion of stoppable trains from the junction/tunnel. Assuming 300m viewing distance, approaching trains travelling at linespeed and with 9%g braking capability

   We calculate that a driver

   - would reach a junction before encountering an oncoming train and that train would have sufficient braking distance from the train accident site in <0.93% of train accidents.
   - would reach a tunnel portal before encountering an oncoming train in <0.19% of train accidents.

   This gives that 44.5% of trains still to reach the junction or tunnel exit may have sufficient distance to stop before the accident site.

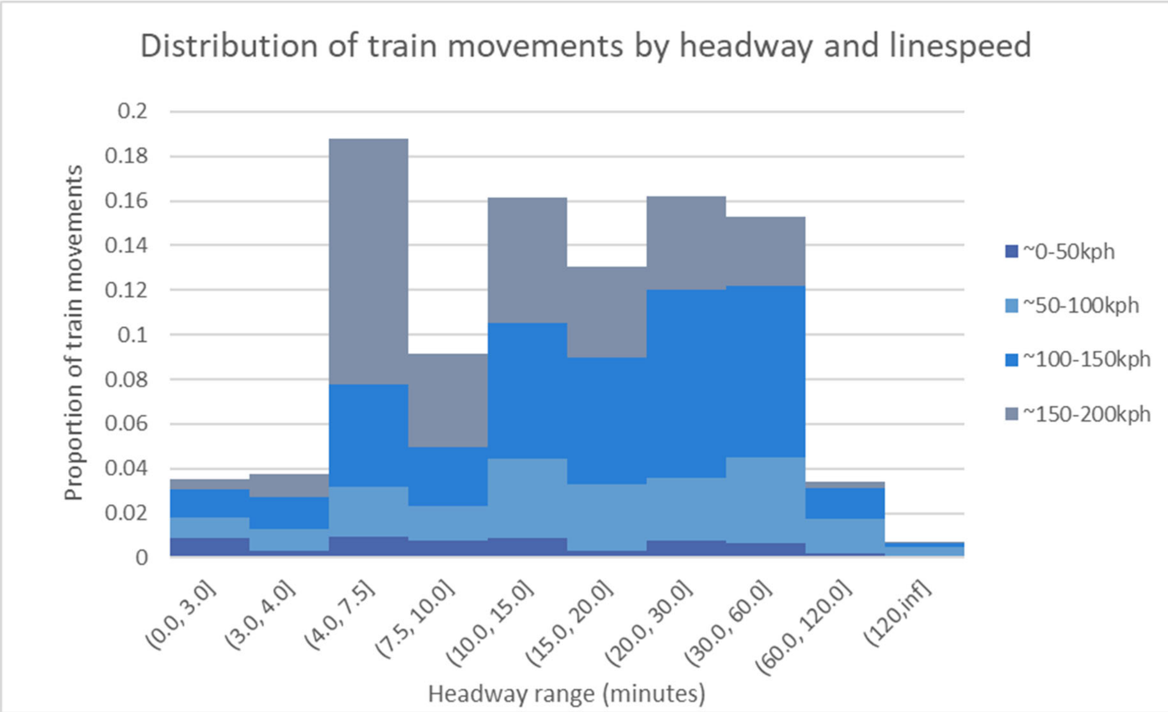
3. The proportion of all train km operated where there is at least 2 adjacent tracks and sufficient headway for a driver to be able to walk 2km forwards, return to their train and then walk further to protect behind their train.

   If a least 60 minutes is required for the driver to do this then we calculate that a driver would have sufficient time to do this in 0.08% of train accidents.

This is thought to be a conservative estimate as this allows for a faster walking speed or shorter time attempting on train communication than under the assumptions for point 1.

4. The distribution of train movements by headway and linespeed to allow for a simple presentation of results from the secondary communication risk model. This distribution is shown in Figure 1.

Figure 1 Distribution of train movements by headway and linespeed calculated from CCT data



5. The average headway per train movements is about 24½ minutes and the median headway per train movement is about 15 minutes.

6. The proportion of approaching trains which are already within braking distance of a randomly located train accident site at the time of the accident and therefore unable to stop is 3.38%

SMIS records

The Safety Management Intelligence System (SMIS) is the rail industry's online health and safety reporting and business intelligence software. It collects and provides access to information on thousands of safety-related events that happen each year on the rail network in Britain.

SMIS contains records of all collisions between trains, train derailments and train collisions with objects. These records were reviewed for details of what communication and protection steps were taken and in what order.

It was found that SMIS does not consistently contain clear information relating to communication and protection actions following train accidents and so no conclusions were drawn from this data.

Secondary Communication Risk Modelling

Output values from the RSSB secondary communication risk model have been used as the basis for risk estimates. Details of the model are available on the RSSB website: Driver-signaller communication and train protection modelling

The key findings from the model are:

- That alternative train cab radios should be attempted in the event of the driving cab radio having failed
- That all on train communication options available to the driver should be exhausted before leaving the train
- That TCOCs should be placed immediately once the driver has left the train cab

There is on average a safety benefit to doing all these things rather than any alternative sequence of actions