Strategy for regulation of health and safety risks - chapter 6a: Track

Strategy for Track

Track integrity is fundamental to safe railway operation (see appendix 1). Recent trends in the management of track assets are positive. Whilst this is welcome, the adequacy of the industry's arrangements for safe stewardship of the track asset remains an ORR priority due to the potential for a catastrophic event. Further, many of the risk control measures for track are vulnerable due to their reliance on human interventions and judgements.

ORR's strategy for regulating the risk arising from the track asset is based on the analysis of duty-holders' performance, inspection, and investigation findings. In particular we want the industry to improve the reliability of its risk control arrangements. We will do this by:

- Engaging with the industry to ensure they develop increasing understanding of the relationship between risk, control, responsible role, competence and assurance;
- Ensuring that improved intelligence about risk prevention and mitigation is translated into effective practical delivery of change (see chapter 3 Change Management);
- Pushing the industry to apply the hierarchy of risk control with elimination of risk at source through the principles of safety by design at scheme and component level (see chapter 12 Safety by Design);
- Encouraging the industry to improve engineering knowledge and innovation so that there is a move towards further engineering control of track related risks and a reduction in the reliance on human systems;
- Focusing on ensuring the delivery of a suitably balanced approach to the management of track, between renewal, maintenance and inspection; underpinned by appropriate knowledge of track asset condition; consequence of failure and appropriate mitigation arrangements that take account of resource constraints.
- Focusing on how the industry is increasing the consistency of implementation of risk-based company control frameworks, through an ever improving understanding of risk control effectiveness linked to assurance activity.

We will continue to give specific attention to ensuring that Network Rail continues to manage the high risk area of Switches & Crossings (S&C) effectively. We will promote improved arrangements for all infrastructure managers to consider track interface risk within their asset management activities and encourage them to work with other rail industry duty-holders to manage wider system risk.

Summary

1. Many of the headline measures for track asset performance particularly for Network Rail and London Underground are at ‘best ever’ or ‘near to best ever’ levels. Both have achieved a notable reduction in the volume of rail defects and broken rails since 2014. However, the on-going challenges associated with significant growth and change, combined with constrained resource, potentially makes these gains vulnerable.

2. The adequacy of the industry’s arrangements for managing the integrity of the track asset remains an ORR priority because of the potential for a catastrophic event should the track fail and the vulnerable nature of risk control arrangements which are sensitive to a range of influences affecting the quality of risk control implementation.

3. The industry has inspection, maintenance and renewal arrangements in place to manage track deterioration. In the context of an aging and increasingly heavily used asset keeping the correct balance between these three elements remains essential to deliver sustainable safety and train performance.

4. Ineffective or inadequate renewal and maintenance arrangements can lead to failures and present precursors to catastrophic train accidents. Fortunately these events are infrequent, but, as illustrated at Potters Bar in 2002 and Grayrigg in 2007, of high consequence. More recent derailments illustrate the consequences of failed track that in slightly different circumstances could have resulted in a catastrophic outcome.

5. Our inspection and investigation findings from track related incidents show that track risk management arrangements are heavily reliant on knowledge, competence and expertise of individuals and that centrally developed strategies and procedures are not implemented consistently. There are very few leading performance indicators to identify potential problems with risk controls before control is lost, or reliably indicate whether the risk control processes are effective.

6. We note and encourage recent developments and improvements in Network Rail and London Underground’s approach to: component design to reduce the risk of human failure; an increasingly clear risk-based framework and the introduction and continued development of automated inspection techniques to improve asset condition understanding.

7. A high proportion of track risk control measures continue to have a lower degree of effectiveness. Many sit towards the bottom of the hierarchy of control, chiefly because of a high reliance on the consistent application of human judgement and activity. The industry should continue to challenge itself to better understand where improvements can be made in its risk control arrangements, including competence and monitoring, so as to increase risk control reliability.

Index of issues discussed

Introduction

1. The track asset forms a critical part of the transport system due to its primary function of providing safe support and guidance to rail vehicles. Its integrity has a direct impact on safety throughout its lifecycle, from design to renewal. The provision and maintenance of safe and resilient track is therefore a primary element of the effective and safe operation of any railway. Ensuring on-going integrity is a key risk control; infrastructure managers should have renewal, refurbishment and maintenance arrangements in place to manage track deterioration risk in order to reduce the likelihood of failure.

2. Track asset is made up of plain line and switch and crossings (S&C). Plain line consists solely of fixed rails set a fixed distance apart; S&C consists of movable rails (driven by point operating equipment) that allow trains to move from one plain line to another.

3. Off track assets are the vegetation on either side of the railway tracks up to the railway boundary, and the physical railway boundary,

4. To give some sense of scale, Network Rail has approximately 32,000 kilometres of plain line track and 17,900 S&C units in running lines; supplemented by some 1,500 kilometres of plain line track and 4,100 S&C units in sidings. On London Underground the concentration and accessibility of the track poses different problems with 45% (429 kilometres) of the 954 track kilometres below ground, the majority of that in deep tube single bore tunnels. London Underground has around 1,800 S&C units, mostly operating within stretches of track operating at slower speeds.

5. Both plain line and S&C are made up of a number of track related components, including rails, sleepers, fastenings, ballast, formation and drainage. Rails can be continuous welded rail (CWR) or jointed. They are attached to sleepers formed from concrete, steel or timber. Rails can also be directly fastened onto longitudinal timbers or concrete slabs in non-ballasted track construction. Each component, when managed correctly (both individually and as part of the track system) contributes to securing a safe railway that reduces the risk of derailment, collision, injury and death.

6. On the mainline network, the average age of overall track assets has increased since the mid 1990's, albeit with some marked differences between individual routes in both age profile and trend. Modern components often have a longer life than those that they are replacing. Rail, in contrast to other track assets, is the only component where the average age has reduced, principally due to the aggressive rail changing policy in the aftermath of the Hatfield derailment in 2000[1].

7. Main line rail traffic has increased by approximately 60% since 1995 and although levelling off for a period during the second half of the 2000's, has again begun to increase. The London Underground network continues to see significant traffic levels; trains travelling over 470 million miles per year and in peak times, up to one train every 90 seconds on the some lines.

8. The track asset life is influenced by, amongst other things: the amount of traffic loading; the type of asset; and level of intervention (renewal, refurbishment, maintenance). Increases in rail traffic as the railway moves towards the 24 hour railway will increase the rate of track wear, and reduce the amount of access available for inspection, maintenance, and renewal.

The Law

9. The Health and Safety at Work etc. Act 1974 is the overarching health and safety legislation relevant to managing the safety of person using the track asset. The general duties under sections 2 and 3 require infrastructure managers to do what is reasonably practicable to secure the health, safety and wellbeing of employees and others. This includes having in place appropriate arrangements to ensure the safe passage of trains. There are a number of statutory instruments made under HSWA that expand on these general principles and deal more particularly with the management of risk arising from trains travelling on track. Most significantly, 'Railways and Other Guided Transport Systems (Safety) Regulations 2006' (ROGS).

10. ROGS gives duties to, amongst others, infrastructure managers, who in the context of the track asset are those responsible for developing, maintaining and managing the track so that it can be used for operating a rail vehicle. Regulations 3 and 4 require infrastructure managers to establish a safety management system that meets the requirements of regulations 5 or 6, and hold a safety authorisation.

11. Regulation 19 of ROGs sets out very explicit duties around carrying out suitable and sufficient risk assessments, and putting in place measures to ensure the safe operation of the transport system. Regulation 4 of the Management of Health and Safety at Work Regulations remains relevant, setting out the principles of prevention that must be applied through the 'hierarchy of risk control'[2].

12. The Railway Safety (Miscellaneous Provisions) Regulations 1997 places responsibility on the infrastructure manager for the railway's boundary measures, based on the principle of preventing unauthorised access to the tracks by people or animals.

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[1] Passenger train derailment at Hatfield, 17 October 2000;
[2] Taking steps to reduce risk by taking preventative measures in order of priority: elimination, substitution, engineering control, administrative controls, personal protective equipment (HSE).

13. Increasingly relevant to the track asset as the railway continues to evolve, are the requirements of the Railways (Interoperability) Regulations 2011 and the associated infrastructure technical specifications for interoperability; and the principles of 'Health and Safety by Design' discussed in chapter 12.

14. We have published 'Principles for health and safety on the railway' to help duty-holders understand our expectations for the high level health and safety outcomes that should be achieved by the railway (the principles) when complying with railway related health and safety legislation. Principles 2.4 and 2.5 – Track and Clearances for trains - are most relevant to this chapter.

Track Integrity & Risk Profile

15. There is a risk of train derailment should the track system lose its integrity or the off-track asset be poorly managed. Track integrity is sensitive to the adequacy of a company's arrangements to manage condition, and the volume (usually measured in equated million gross tonnes) and speed of rail traffic. Whilst the risk is greater for the S&C, there are some key features common to both plain line and S&C that can initiate derailments.

16. The principal derailment risks relating to track and 'off-track' asset (figure 1) are:

- track geometry faults (including twist, cyclic top)
- S&C faults
- track buckle
- loss of rail integrity (including broken rail, rolling contact fatigue (RCF), rail defect)
- gauge spread
- broken fishplates
- trains striking fallen trees and other objects placed on the line
- animals on the line

17. Poorly maintained vegetation can also obscure sighting at signals and user worked level crossings, and the safety of workers on or near the line. Poorly maintained boundary measures can also increase the likelihood of trespass incidents and theft of assets. (See Interface chapter 5 for further information).

18. Asset condition is maintained through a mixture of renewal, refurbishment and maintenance, all underpinned by inspection. All are dependent on continued human intervention to the right quality, at the right time and in the right location. Should the incorrect balance be delivered, or should there be under-delivery without adequate adjustment to other aspects, track condition will decline due to environmental factors and the passage of trains. This leads to an increased risk of failure and potential derailment. There have been derailments, including Gloucester[3] and Primrose Hill/Camden[4], where sufficient action was not taken to prevent deterioration and this ultimately led to a train derailment.

19. Track integrity can impact on, and be impacted by other railway engineering disciplines. For example: the run on/off approaches to under-bridges can increase the risk of voiding and imposed load on the rail; embankment condition can influence the quality of

[3] Freight train derailment near Gloucester 15 October 2013
[4] Freight train derailment at Primrose Hill/Camden Road West Junction 15 October 2013

track geometry, and the lack of suitable drainage infrastructure impact on the quality of track drainage provision. The position of the track in relation to other railway assets can have a significant impact on railway safety: the maintenance of suitable clearance between track and platform and other structures; track alignment and overhead wires or third/fourth rail, and the impact of track geometry profile on level crossing profile and surfaces. (See Interface chapter 5 for further information).

20. The consequences of derailment will be dependent on a number of factors, including speed, location, environment (number of lines, embankment, cutting, bridge etc.), surrounding topography and train type (freight / passenger) and rolling stock type. Elements of these factors will be dependent on circumstances and chance, but they determine the seriousness of the outcome (whether there is potential for collision, for example). Despite this uncertainty the clearly foreseeable consequence is multiple fatalities. Likelihood can be kept very low if the correct control measures are in place.

Mainline – Network Rail

21. As the largest infrastructure manager regulated by ORR, Network Rail has made concentrated efforts to improve its stewardship of the track asset from the position inherited from Railtrack. The Hatfield derailment in 2000[5] when four people were killed illustrated the inadequacies of Railtrack and their contractors' arrangements. The aftermath revealed an unacceptable deterioration in track condition due to underinvestment resulting in the imposition of approximately 850 emergency speed restrictions. Network Rail itself has also had to learn the lessons from fatal accidents due to track faults: failed stretcher bars at S&C at Potters Bar in 2002, when Railtrack were in administration and at Grayrigg in 2007.

22. Network Rail has undertaken a number of steps to secure improvements in the safe management of track since it took over from Railtrack in October 2002:

- It has brought maintenance back in-house
- It has undertaken significant track renewal and refurbishment activity
- It has reviewed & enhanced process and introduced new intervention limits
- It has analysed the strengths and vulnerabilities of its control measures through use of bow tie analysis
- It has tried to bring greater clarity to its instructions and procedures through the Business Critical Rules (BCR) programme and make a more explicit link between competence, intervention, and control of risk
- In conjunction with its BCR programme it has made a clearer identification of roles and responsibilities and changed its competency management system to align with these roles and strip out 'unnecessary' competence requirements.

23. The characteristics, risk profile and performance of the track asset are discussed in detail in Appendix 1. Generally, track geometry and rail performance is improving, and in some cases, such as broken rails and serious rail defects, at historically low levels.

24. This improving performance is in some part due to increased investment following Hatfield, and new technology. The introduction of pedestrian and train borne ultrasonic test unit (UTU) Sperry ultrasonic rail testing equipment and automated inspection techniques

[5] Passenger train derailment at Hatfield on the east coast main line; October 2000

such as plain line pattern recognition (PLPR) have brought consistent and reliable supplements to the existing train borne systems to measure track geometry. UTU and PLPR have also brought a worker safety dividend by reducing track workers exposure to moving trains.

25. Technological improvements are welcome, but the preponderance of risk controls still rely on human knowledge, skills and judgement. Network Rail has not yet consistently and sufficiently well embedded BCR and role based competence management to realise the full potential of these programmes targeted at improving consistency and reliability of people-based processes.

26. ORR continues to make the management of track assets a top priority for its work – despite historically 'best ever' lagging indicators – because:

- Rising traffic levels can increase the rate of asset degradation, particularly on older track forms.
- Increasing traffic levels also typically reduce access availability to deliver maintenance and renewal activity, and increase the impact of failures due to the more congested network.
- Reducing the level of planned renewal activity will place greater reliance on inspection and maintenance activities.
- These conditions are increasing pressures on staff and already vulnerable control measures.
- We find highly varied RM3 ratings revealing inconsistent and not well developed management maturity.
- Taken together these factors are sufficient to cause ORR to have concerns about how sustainable recent improvements will prove to be. Developing more meaningful leading safety performance indicators would allow Network Rail to more reliably identify early, and before failure, areas of weakness that can then be addressed to support making current performance sustainable.

Transport for London – London Underground

27. London Underground's engineering approach to reducing risk arising from its track asset is similar to Network Rail's; designing out risk and improving the identification of risk precursors and serious defects.

28. Following a rise during 2012 and 2013 London Underground (LU) has more recently seen a resumption of a downward trend in rail defect numbers. Since 1983, 83% of rail breaks were in bull head rail; 33% of these at joints. London Underground's significant investment in track renewals to design out risk has replaced jointed bull head rail with continuous welded flat bottom rail on concrete sleepers or direct fix slab track to improve rail integrity. London Underground has also introduced new monitoring and inspection techniques to improve its understanding of asset condition.

29. The residual risk associated with rail breaks remains but since 2010 London Underground has only recorded 13 breaks in flat bottom rail.

30. London Underground’s longer-term move away from traditional jointed rails on wooden sleepers, to a more modern track configuration of flat bottomed continuous welded rail on concrete sleepers has also reduced the potential for gauge widening and track twist.

31. Track quality is improving across all lines, the amount of track classed as ‘most serious’ reducing consistently since 2013/14. Track quality discrete fault numbers have also been falling consistently since early 2013/14.

32. The increased use of track recording vehicles and automated track monitoring systems provide greater understanding of how the track performs under load, allowing track geometry faults to be identified prior to visual identification.

Trams & Light Railways

33. Tramways are more modern networks than other UK rail networks and purpose built. However, some networks also use heavy rail track sections inherited from previous urban railway operations. These rail sections are susceptible to the same risks as on the mainline although trams speeds are lower meaning that the track is over engineered for its use.

34. There is a particular issue about grooved rail in street-running areas where road vehicles, cyclists and pedestrians share the same space as the trams. The design and maintenance, therefore, must not introduce additional hazards to these other road users. This also limits the design and placement of associated hardware, for example, signalling equipment.

35. A tram derailment in a congested shopping high street introduces additional risk to pedestrians and others that is not generally present in other railway networks. Derailments have occurred at the intersection between road running and track sections.

36. Tramways utilise trail-able points to make both in service and emergency facing moves. Whilst generally at low speed, there have been a number of derailments on UK tramways where trams have “split the points” due to the point blades moving under a passing train due to incorrect adjustment of the points mechanisms. This has resulted in significant disruption and often requires detrainment with the attendant risks of passenger accidents.

37. Trams may run on significant slopes and are fitted with magnetic track brakes to provide additional braking which is not seen on the mainline.

38. The selection of staff and maintaining their competence is a key factor in avoiding poor maintenance of assets and ensuring that the risks at the interface are kept low.

39. It is essential that tramways have appropriate standards for the inspection of their specific infrastructure, action levels and maintenance documentation. ORR expects tramways to have robust inspection and maintenance regimes for all differing points mechanisms on UK tramways. The use of standards from the mainline railway is often inappropriate for tramway components and using such standards unquestioningly can import risk.

Heritage Railways

40. Most heritage railways have installed used serviceable rail from the mainline and it may be nearing the end of its engineering design life (hence removal from the mainline). Checking management of track wear by the operators is a particular priority for us as a precursor to failure and subsequent derailment risk.

41. We find that some heritage railways do not have a sustainable renewal policy or funding available for large-scale rail renewal. There can be an absence of standards for track appropriate to their heritage use, as the mainline standards may no longer be appropriate. We expect heritage railways to have systems in place to monitor wear and staff competent to do so.

42. The heritage sector continues to grow in popularity and when normalised for its size, potential for infrastructure failure is probably disproportionately greater than other networks. This is attributable to the age of the assets and the largely volunteer nature of its workforce. However, consequences are generally less severe due to the lower speeds prevailing.

Challenges

43. There are a number of challenges that can restrict effective control of risk arising from track:

- **Reliability of controls**: Network Rail has developed a relatively mature set of standards and process that are capable of controlling risk of derailment due to loss of track integrity. Although automated inspection techniques are becoming more common, effectiveness of these controls is largely reliant on human application, judgement and intervention that sit towards the bottom of the hierarchy of risk control (e.g. not engineering based; and no fail to safety). We have evidence that these control measures can be poorly delivered at an operational level. Organisational culture, competence, and monitoring and review arrangements are fundamental to ensuring effective risk control. The move towards a risk based standards framework, through the introduction of the Business Critical Rules (BCR)[6] framework in the mainline network for example, has the potential to increase the clarity and effectiveness of risk controls, if introduced and comprehensibly embedded so as to realise the potential benefits. We note there is action being taken to increase control effectiveness. Within plain line for example, inspection of key risks is increasingly reliable through use of automated inspection arrangements.

- **Monitoring arrangements**: The reliance on human judgement and intervention to implement risk controls increases the reliance on monitoring and review activity to provide confidence risk is controlled as intended. There is an absence of high quality tactical monitoring arrangements and leading indicators to identify potential problems or reliably indicate risk control effectiveness, before the asset fails.

- **Sustainable repairs**: Keeping the correct balance between maintenance and renewal activity is essential. The proportion of track geometry faults that are repeats – up to 60% in some instances – indicates that achieving sustainable repairs remains challenging in the environment of reducing renewal and refurbishment volume. In

[6] Risk based framework comprising of rules, means of control, competence requirements, and assurance arrangements

many instances, such as cyclic top and the most severe geometrical faults, maintenance interventions will only achieve short term fixes that will require repeated monitoring activity and interventions, acting as a distractor from other proactive work to prevent deterioration elsewhere.

- **Growth & increasing demand combined with constrained resource levels**: the on-going challenge of managing rail traffic growth, and resource constraints (in terms of people, reducing access & move towards a 24 hour railway on the mainline, and introduction of the 'night tube' on London Underground), equipment, renewal activity, refurbishment) to deliver a safe and efficient railway; resulting in reducing access for track maintenance & renewal activity leading to a greater reliance on the effective management of maintenance & renewal activity targeted at highest risk areas.

- **Granularity of data**: Network Rail's recognised measures indicate that track asset performance at a national level is improving with some measures at 'lowest ever' values. This positive national performance is not reflected universally or consistently across Network Rail and potentially masks local performance challenges. There is a lack of easily accessible information at a granular level to provide visibility of track asset performance to monitor performance and allow effective targeting of finite resource.

- **Interaction between track and freight vehicle**: particularly in relation to those vehicles that are more sensitive to track condition closer to intervention limits.

- **Interface with other disciplines** that can impact on track risk control effectiveness, and vice versa: structures, geotechnical structures, electrification overhead wires.

ORR priorities

44. Within each priority below, we reference the most relevant Risk Management Maturity Model (RM3) sub-criterion and level to illustrate the goal area we believe the industry should be moving towards.

45. Increasing understanding of the relationship between risk; control and its effectiveness; responsible role; competence; and assurance. Within the main line industry, we see the delivery of the BCR programme as an important element in supporting this improved understanding. Focus particularly on track geometry and S&C risk. (SP1 – Leadership: level (4) predictable; OC6 - Organisational culture: level (4) predictable & (5) excellent)

46. Move away from a standards based approach to one increasingly based on risk, such as the principles that form the BCR framework and reliability centred maintenance. (RCS2 - Management of asset: level (4) predictable)

47. Improved engineering control of risks and move towards elimination of risk at source rather than reliance on reactive human systems to secure adequate risk control; with a move to remote condition monitoring, automation, and further implementation of safety by design principles and innovation. (PI1-Risk assessment & management: levels (4) predictable & (5)excellent); RCS2 - Management of asset: level (4) predictable)

48. Better understanding of underlying asset condition and performance, to a granular level at local level; the risk presented; and the controls required and implemented until renewal or removal of the risk. A fundamental element of this approach is knowing the problem, and understanding and addressing the root cause rather than a symptom. Linked to need for a track maintenance strategy and supporting plans that set out the short, medium and long term goals and resources to deliver those goals delivering an informed balance between renewal and maintenance activity. (OC7 – Record Keeping: level (4) predictable and level (5) excellent; PI3 - Workload planning ; level (4) predictable); RCS2 - Management of asset: level (4) predictable)

49. Robust monitoring and review arrangements, with focus on developing leading indicators, and improvements in supervisory and monitoring arrangements at a tactical level. (MRA1 - Proactive monitoring arrangements level (4) predictable and level (5) excellent; MRA4 - Management review; MRA5 - Corrective action: all level (4), predictable)

ORR activities

50. **Risk Control Implementation**: Given the potential for multi-fatality events arising from track defects, we will continue to verify, through proactive inspection, the effective implementation of industry's arrangements intended to manage risk associated with the track.

51. **Risk Control Implementation, S&C system**: We continue to identify the S&C system as a priority risk area due to its complexity, potential failure modes and reliance on individuals to control risk. We will continue to challenge the industry's safe management of S&C, including knowledge and understanding of the asset; design of risk control measures; efficacy of the inspection and maintenance arrangements to manage identified risks; and encourage its plans to reduce reliance on human intervention to secure adequate risk control through automation and safety by design.

52. **Investigation:** We will investigate selected incidents to identify lessons to be learned in the management of track risk, and to ensure suitable corrective actions are identified and acted upon.

53. **Learning Lessons:** We will ensure that the industry properly and proportionately implements RAIB recommendations; and ORR investigation findings and inspection action points; doing so through inspection programmes and where necessary formal enforcement.

54. **Enablers**: Within the main line railway, Items 55 to 57 below are closely related to the development, roll out, and implementation of the risk based framework known as Business Critical Rules Programme (including Role Based Capability and Skills Assessment Scheme) within the Track Discipline. We consider these activities to be enablers to assist the more effective management of the track asset, in terms of safety, performance, and reliability.

55. **Control reliability**: The industry should apply the principles of the hierarchy of risk control and 'safety by design' as set out in chapter 12 of our strategy when planning new or modified track works or process[7], at both a system and component level to avoid or reduce

[7] Management, installation, inspection, maintenance, removal

future hazards, by increasing control effectiveness and reducing dependence on human activity to achieve suitable levels of risk control. This should include developing new technologies that will reduce reliance on human judgment alone; and looking for opportunities to remove redundant assets where possible.

56. **Competence:** We will monitor the industry's activity to increase its focus on developing, maintaining, and assessing competence at all levels to allow it to grasp the full potential that its move from heavy reliance on prescriptive standards to a more risk based approach can provide; as per chapter 2 'staff competency' of our strategy.

57. **Monitoring / Indicators:** Push the industry to develop its monitoring arrangements by:

- Continuing to develop its lagging indicators so as to provide greater visibility of track performance and level of risk at a local level to allow more effective use of constrained resource to manage risk.
- Develop leading indicators, to complement its current suite of lagging indicators, to improve its monitoring arrangements to verify that the risk control system is operating as intended, or provide early warning that problems are starting to develop.
- Developing its tactical assurance arrangements to provide confidence that risk control measures are being implemented to an adequate quality to secure reliable and consistent level of safety and asset performance.

58. **Maintenance balance:** Encourage the industry to move from a 'find and fix' to a 'predict and prevent' culture underpinned by appropriate knowledge of the assets and consequence of failure; leading to an increasingly proactive, effective and efficient management of the track asset through the provision of risk based maintenance and renewal plans.

59. **Tramways:** Wheel rail interface and derailment risk for tramways continue to be our main focus on activity.

60. **Heritage Railways:** We will continue to carry out inspection and investigations with track a priority. We will continue to work with the Heritage sector to ensure guidance specific to their needs is developed for infrastructure inspection and maintenance.

Appendix 1: Characteristics of the Mainline – Network Rail

1. The RSSB Safety Risk Model[8] defines the overall modelled risk on the railway. Whilst the risk of derailment from track failure is a small component of the overall risk, it remains important. The latest version (v8.1) published in December 2014 shows train accidents make up around 6% of all risk; derailments around a quarter of this (1.5% of all risk).

2. RSSB's Train Accident Precursor Indicator Model (PIM) measures the underlying risk from train accidents by tracking changes in accident precursors (in the past 12 months) and is calibrated against the Safety Risk Model.[9] The PIM indicates that long term risk associated with track equipment continues to broadly decline (Figure 1) making up around 5% of the total PIM score. As shown in Figure 2, two trends are particularly noticeable:

- S&C failure rate is broadly declining since 2010 reaching its current relatively stable position 50% below the CP4 exit figure.
- The reported risk from track twist and geometry faults is rising from a historic low point in mid-2013/14 to be the highest risk precursor; which goes against the mainline indicators that show track geometry performance (condition achieved) to be at best ever levels. However, PIM recorded performance is only based on the most serious track faults and doesn't take into account wider track geometry fault performance and as such is sensitive to small changes due to the small data set.

Table 1 shows the relative PIM contribution from the principle track failure modes. As the PIM is a lagging indicator providing information on past performance, its use is limited as an indicator of future performance.

[8] SRM v8.1

[9] http://www.rssb.co.uk/risk-analysis-and-safety-reporting/risk-analysis/precursor-indicator-model

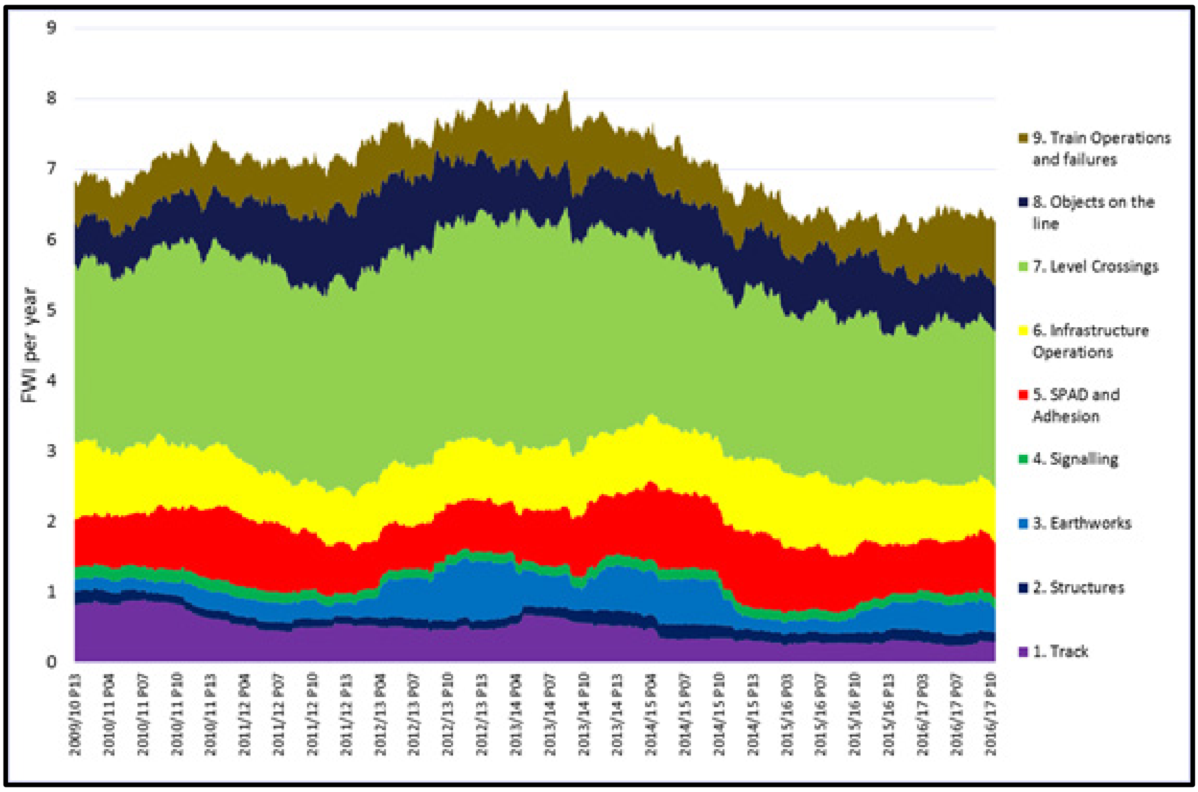


Figure 1: PIM – Total Risk, period 10 2016/17

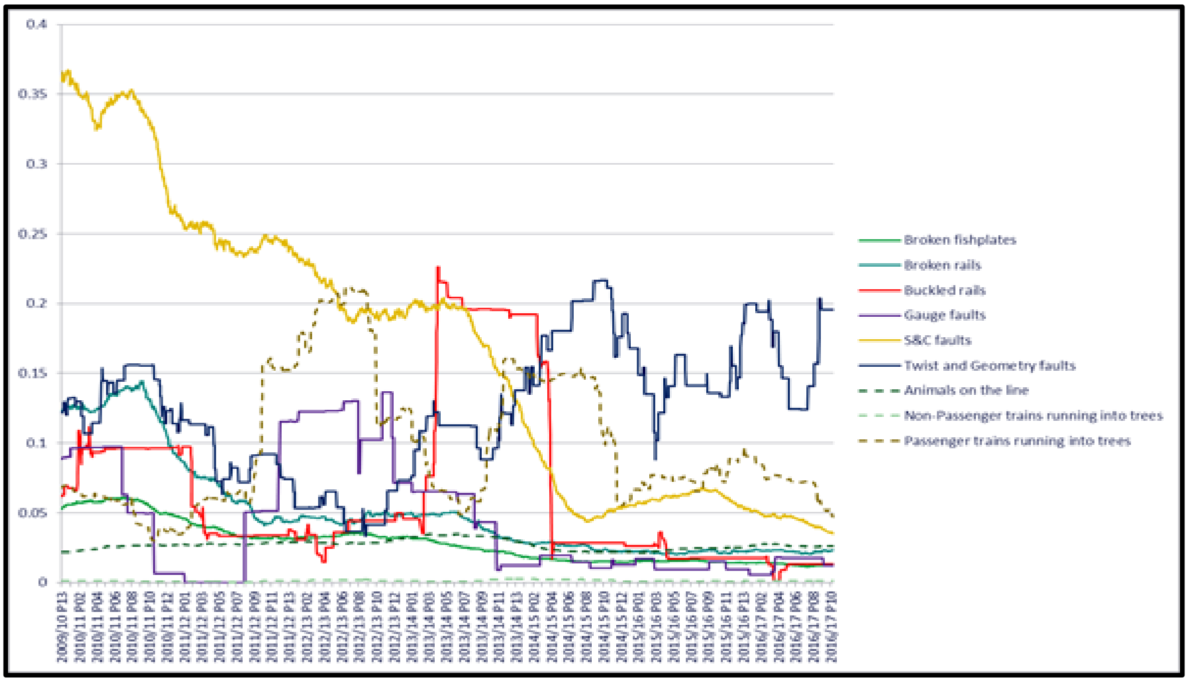


Figure 2: PIM Contribution, Track; period10 2016/17

Asset	Failure Mode	PIM precursor (FWI/yr)	Contribution to safety risk from track
Rail	Broken Rail	0.022	7%
	Buckled Rail	0.017	5.4%
	Broken fishplate	0.014	4.5%
Sleepers	Gauge spread	0.010	3.2%
Ballast	Track twist & geometry	0.199	63.4%
S&C	S&C	0.052	16.2%
Total Track		0.314	100%

Table 1: PIM Contribution from Track at end 2015/16; source: RSSB

3. Network Rail's overall approach to risk reduction focuses on designing out risk, and improving risk pre-cursor and serious defect identification capability to allow earlier mitigation and repair.

4. Our inspection findings indicate that the mainline railway is managing immediate risk, but many of the controls are vulnerable. Levels of compliance with key company standards and processes in place to manage track geometry risk varied across delivery units, with some significant failings identified. Within Network Rail, the level of compliance at a local level appeared to be influenced by the level of attention given to them by Network Rail Safety, Technical and Engineering (STE) or ORR.

5. This control vulnerability is shown in Network Rail's own low assessment of the effectiveness of the majority of its control measure to manage track risk due to the reliance on workers implementing process correctly; which can be influenced by external factors such as access pressures and environmental conditions. There is a tendency to deliver some form of repair, rather than the structured review required to determine the most suitable repair for the medium to long term.

Track performance

Track geometry

6. There has been a marked improvement in track quality performance at national level as measured by the 'good track geometry' and 'poor track geometry' indicators between 2000/01 and 2009/10. Track geometry performance worsened during the first half of CP4 before recovering and continuing to improve into CP5, although with regional variation. (See appendix 2). **Super red eighths** (SRE), the poorest classification of track geometry requiring immediate action, are also broadly trending downwards, as are repeat SREs (70% of total SRE numbers), but at a smaller rate. More recent performance indicates that further improvements may be harder to achieve, and recent gains are vulnerable.

7. Whilst not a direct safety indicator we monitor discrete track fault levels that require a response within a mandated timescale as they provide a useful precursor indicator to track condition. Repeat fault numbers provide an indication of repair effectiveness. Discrete fault numbers have seen a similar trend to poor track geometry: a significant reduction between

2000/01 and 2009/10 before levelling off and deteriorating in the first half of CP4. The improving trends achieved in the second half of CP4 has been broadly maintained into CP5, the number of discrete track geometry faults now around 9.5%% less than at CP4 exit.

8. **Track twist** is a specific type of higher risk track geometry fault that is a common cause of derailment. Nationally total twist fault numbers reduced by 27.3% on CP4 exit at period 10 2016/17. After rising during 2011/12 to 2013/14, and following intervention by ORR, repeat twist fault numbers have decreased (at period 10 2016/17 repeat twist faults down over 9% on CP4 exit) but performance remains variable, earlier gains during CP5 now being lost. It remains unclear if Network Rail will meet its own national CP5 repeat fault reduction targets. As new twist fault numbers fall quicker than repeat faults, over 50% of twist faults continue to be repeat faults indicating that effective and sustained repair of this category of fault remains challenging.

9. **Cyclic top** faults are a particular type of track geometry faults that increase the likelihood of freight train derailment. The level of risk is speed dependent and has potential to increase in significance as the track formation ages or deteriorates for example due to poor drainage. Risk can be effectively controlled by imposing speed restrictions on freight vehicles until the fault is repaired. The effectiveness of using speed restrictions as a control rely on reliable asset performance information, correct application of process requirements, and accurate assessment of the quality of the repair. Since the middle of 2013/14, following intervention by Network Rail centre there has been a marked and sustained increase in speed restrictions associated with cyclic top, despite a decreasing trend in cyclic top sites, indicating improved and more reliable application of process.

10. **Combination faults**, where two or more different track faults occur together can increase the risk of derailment and potentially require earlier intervention than mandated timescales, based on an engineer’s assessment of their combined impact. Similarly the risk of derailment can increase where the track, rail vehicle, and/or load is close to, at, or beyond allowable tolerances. The Cross Industry Freight Derailment Working Group[10] initiated by ORR has been formed to examine this system safety issue.

11. Provision of **effective drainage** is a fundamental requirement in maintaining track in good condition; poor drainage is an underlying cause of track formation failure that will adversely affect track geometry, cause more rapid deterioration, and create a potential derailment risk. Until recently, Network Rail had neglected its drainage systems; it’s recent creation and filling of a new ‘Head of Drainage’ is positive. There remains work to be done to deliver effective inspection and maintenance of all drainage assets. The output of the Integrated Drainage Project is a vehicle to make the necessary improvements.

S&C Integrity / guidance of train wheels through S&C systems

12. We treat S&C as a separate system within the track asset category. S&C presents a rail discontinuity to the rail vehicle wheels and this, combined with the increased dynamic forces on infrastructure and vehicle result in the vehicle being inherently less stable as it

[10] http://www.rssb.co.uk/risk-analysis-and-safety-reporting/accident-investigation-and-learning/tackling-freight-derailments

passes over S&C. As illustrated by the derailments at Potters Bar [11] and Grayrigg [12] the consequences of failure can be high, and are potentially significantly higher than for other types of track related failure.

13. A key feature of S&C is that it should be managed as a system, combining both track and signalling asset knowledge. Designing and maintaining correct switch profile and position to the correct parameters prevents increased forces in the system that can result in degradation and un-commanded switch rail movements that ultimately can result in a train derailment.

14. The rail industry's current approach to managing risk at S&C is heavily reliant on human beings who implement the inspection and maintenance requirements of various standards. The industry recognises this and is developing engineering solutions to design out risk, and improve the early identification of risk precursors and serious defects. Network Rail is increasingly moving to a risk based approach to managing and maintaining S&C based on an increasingly detailed understanding of their design, engineering science, and safety requirements. Complementing this approach Network Rail is in the early stages of developing automated S&C inspection equipment that would provide reliable and repeatable inspection data on a key derailment risk.

Track Buckle

15. The number of buckles that currently occurs on the main line network per year is principally linked to climatic conditions, as demonstrated by the rise in numbers of buckles in the hot summers of 2005 and 2006. As such the level of risk indicated by the PIM is driven by climatic conditions and the consequence of observed buckles.

16. Buckle risk control measures take on three elements: initial integrity delivered through correct stress free temperature and installation and subsequently maintained integrity during maintenance interventions; asset knowledge knowing the location of higher risk sites due to asset condition and environmental factors; and arrangements to monitor rail temperature and take appropriate action at the correct time. The latter two elements in particular rely on human intervention and application of process. Potential to improve effectiveness through remote monitoring has the capability to introduce an element of automation.

Rail integrity

17. Rail defects increase the likelihood of a rail breaking; similarly cracked or broken fishplates lead to the same outcome: an uncontrolled discontinuity in the rail running surface.

18. There has also been a notable reduction in the number of rail defects, broken fishplates and broken rails since 2000 when 952 broken rails were reported. In 2015/16 Network Rail had 109 broken rails, and although slightly up on the historically low of 98 reported in 2014/15, represents a 90% reduction in 15 years at a time when traffic levels rose significantly.

[11] Passenger train derailment at Potters Bar on 10 May 2002, killing six passengers and one member of the public.
[12] Passenger train derailment at Grayrigg on 23 February 2007, killing one passenger

19. These improvements are due to substantial and sustained improvements in rail management after the Hatfield derailment in October 2000, and includes a better understanding of causes, significant re-railing; improved site welding processes; improved and more frequent ultrasonic testing techniques (ultimately leading to the current train borne solution); and the introduction, and then tightening of intervention levels for rail joints.

20. Over CP4 and into CP5 we see a continuing steady increase in heavy and severe **rolling contact fatigue** (RCF) across the network. This has been the result of changing standards; challenges around accurate visual identification and measurement; and reduced volumes of rail grinding in both S&C and plain line. Network Rail is in the process of introducing a new inspection regime based on eddy current testing processes that will provide a more reliable and accurate picture of RCF across the network.

21. Although the number of **rail breaks** due to foot corrosion and weld failure are falling, they form an increasing proportion of all rail breaks. Between 2010 and 2016 the proportion of rail breaks due to foot corrosion has risen by 9%, to nearly half of all rail breaks. Conversely the proportion of breaks due to weld failure has dropped 13% to16%. This shift is likely to be due to the aforementioned improvement in welding technique, but importantly partly due to the impact of localised deteriorating track geometry affecting support conditions and increasing intensive use of the rail.

Gauge

22. **Track Gauge** – the horizontal distance between the running edges of the track – is essential to deliver satisfactory track geometry and uniform rail wear, and ultimately to prevent derailment through gauge spread. Historically low levels of gauge faults were affected by the inclusion of tight gauge data since 2014/15.

23. **Tight gauge** is generally associated with construction activity, and initial quality of sleepers / bearers; or as a result of not properly controlled heavy maintenance or refurbishment activity. Whilst not likely to lead to a derailment event alone, tight gauge will potentially affect ride quality and train / rail interface leading to increased degradation of associated components.

24. **Wide gauge** is more associated with asset degradation, and is managed through track inspection and maintenance activity. Longitudinal timbers present a natural discontinuity in the track support system leading to potentially increased dynamic forces. This, combined with a construction form that can increase the risk of wide gauge and alignment defects can lead to the need for enhanced inspection and maintenance requirements involving other engineering disciplines to assess condition.

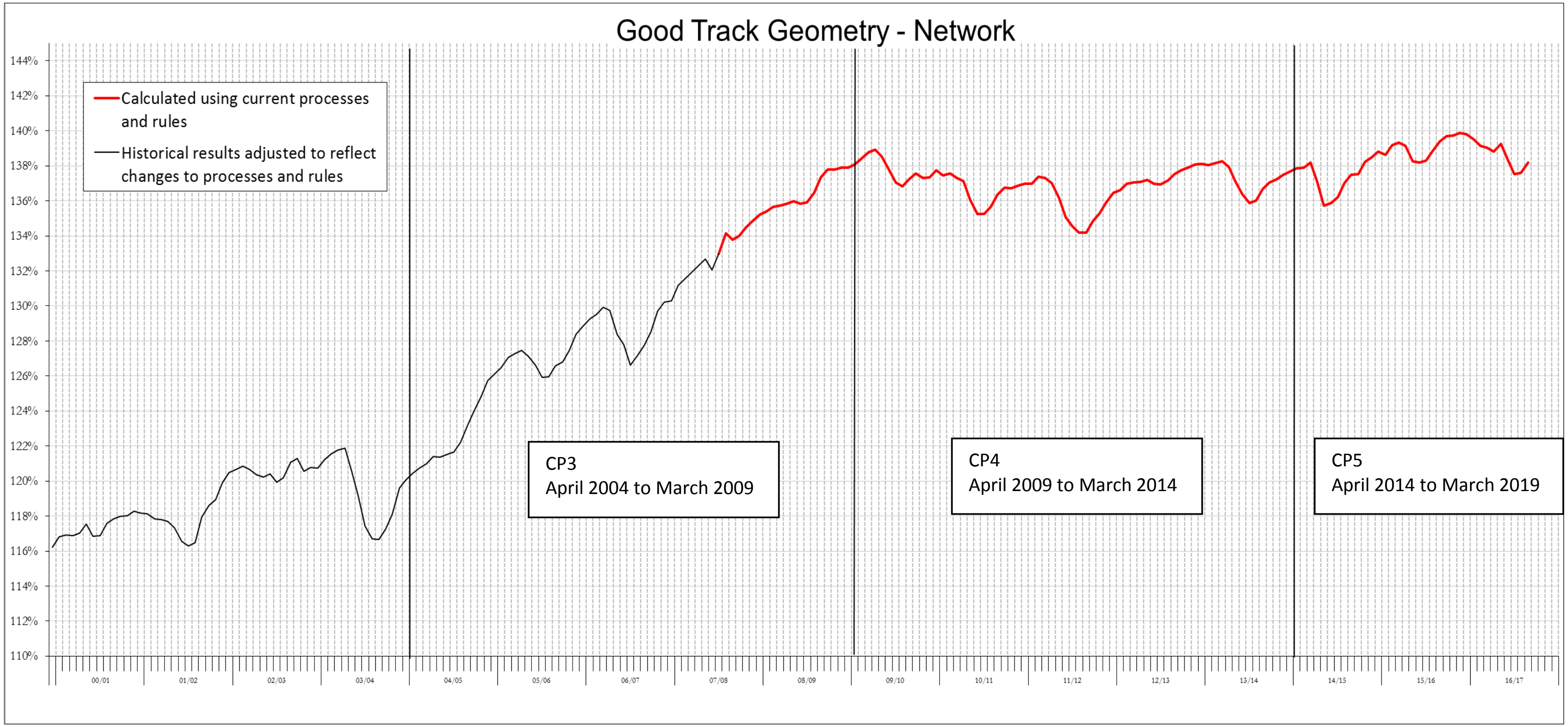
Off-track

25. The primary reason for managing vegetation to allow the safe passage of trains and prevent it physically obstructing the efficient management of other assets. There have been a number of derailments in the past 10 years due to trains striking fallen trees, and Network Rail state one of the main cause of signal failures is due to vegetation obscuring them. Network Rail continues to develop its understanding of its vegetation asset and work required to move away from its previously reactive approach to compliance with its new risk based requirements.

26. RSSB analysis (2014) of the risk from animals concluded that the industry has reduced the risk arising from animal incursion through improvements in fence management, rules for reporting incidents, and robust train design. Between 2003 and 2014 the number of animals accessing the line reduced by 40%; but in the same period there was a significant increase in the number of trains striking animals, the increase largely driven by increased deer strikes that is probably related to the rapid increase in deer numbers in recent decades. There is also an increasing trend in livestock incursion wrong side failures. Passenger trains do derail when striking cattle, as illustrated at Letterston Junction (2012) and Godmersham (2015) where fencing management was poor, and can be fatal, as illustrated in Germany in 2012. Therefore accurate knowledge of land use and fencing condition remains a critical part in understanding any changing risk profile; and identifying changes in fencing type and level of effective maintenance to manage risk.

Appendix 2: Supporting Information

Network Rail: Good Track Geometry: Long Term Trend on Mainline Network



Network Rail: Poor Track Geometry: Long Term Trend on Mainline Network

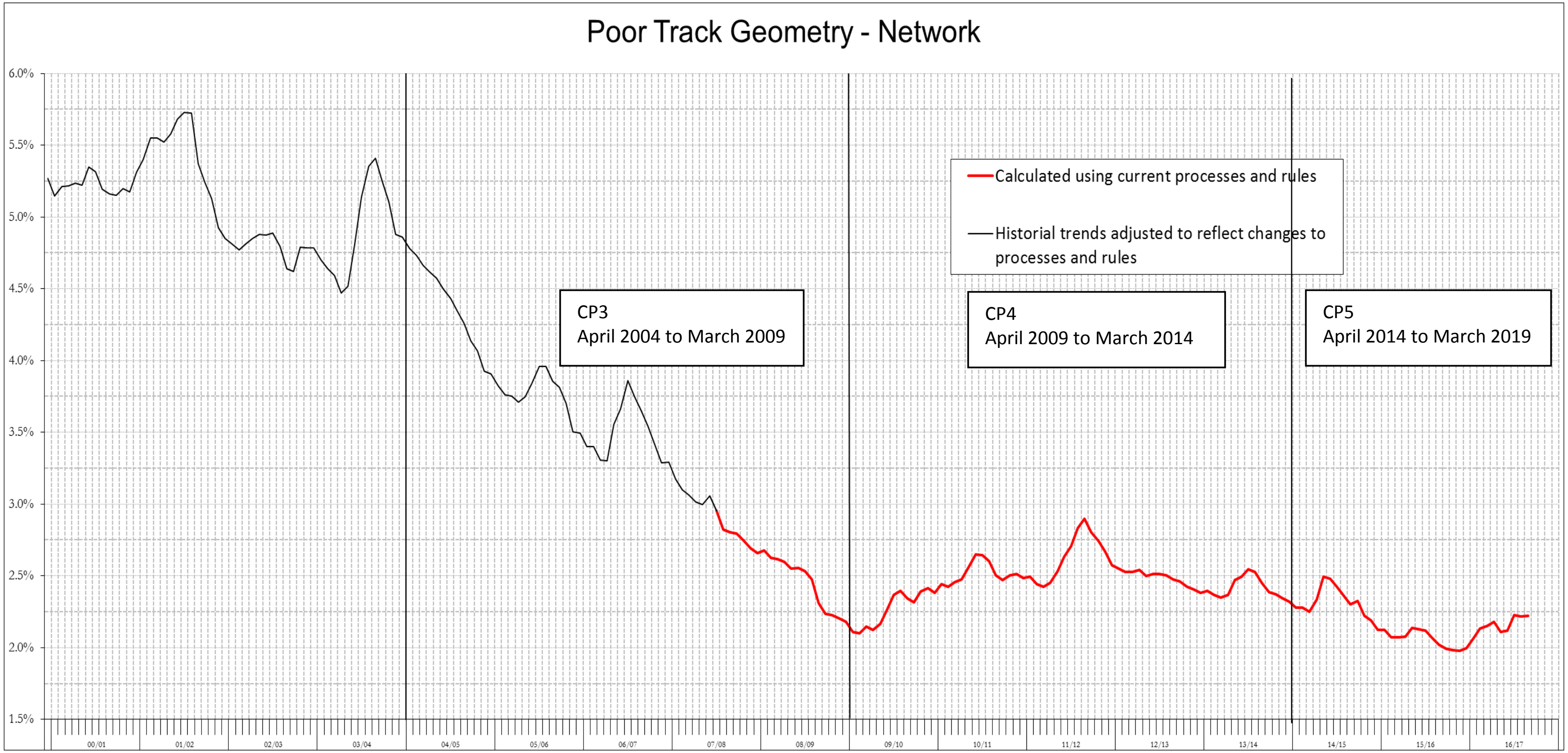


Figure 1: PIM – Total Risk, period 10 2016/17

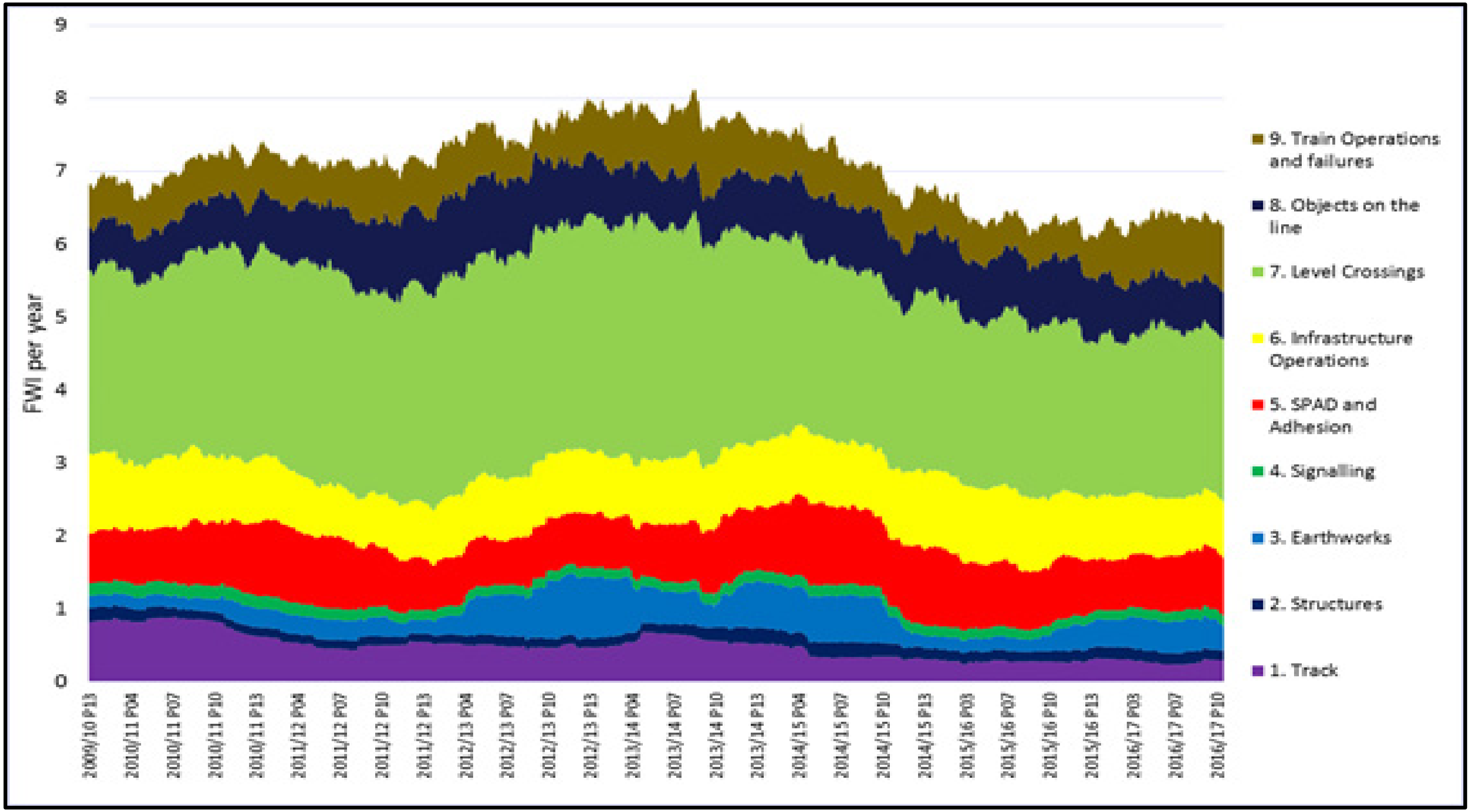
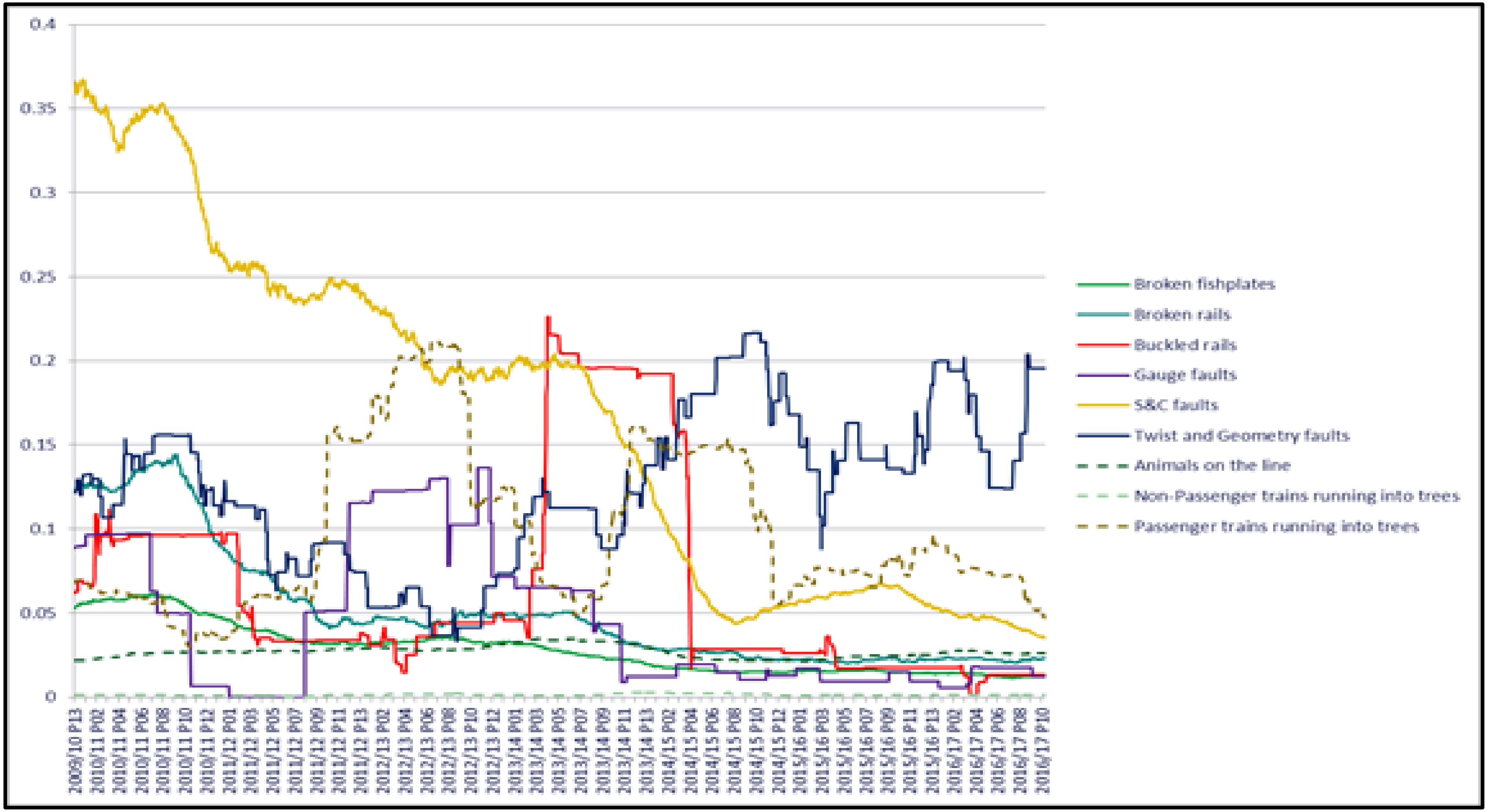


Figure 2: PIM Contribution, Track; period10 2016/17



Appendix 3: Glossary of terms

Glossary of terms	
Acronym	**Definition**
BCR	Business Critical Rules
CP	Control Period
CP1	April 1996 to March 2001
CP2	April 2001 t0 March 2004
CP3	April 2004 to March 2009
CP4	April 2009 to March 2014
CP5	April 2014 to March 2019
CP6	April 2019 to March 2024
CWR	Continuous welded rail
HS1	High Speed 1 railway line
HSE	Health and Safety Executive
FWI/yr	Fatalities and weighted injuries per year
LU	London Underground
NR	Network Rail
ORR	Office of Rail & Road
PLPR	Plain line pattern recognition (train)
PIM	Precursor indicator model
RCF	Rolling contact fatigue
RM3	Railway management maturity model
ROGs	Railways and Other Guided Transport Systems (Safety) Regulations 2006
RSSB	Railway Safety and Standards Board
S&C	Switches and crossings
SRE	Super red eighth
SRM	Safety risk model
STE	Safety, Technical and Engineering
UTU	Ultrasonic test unit

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