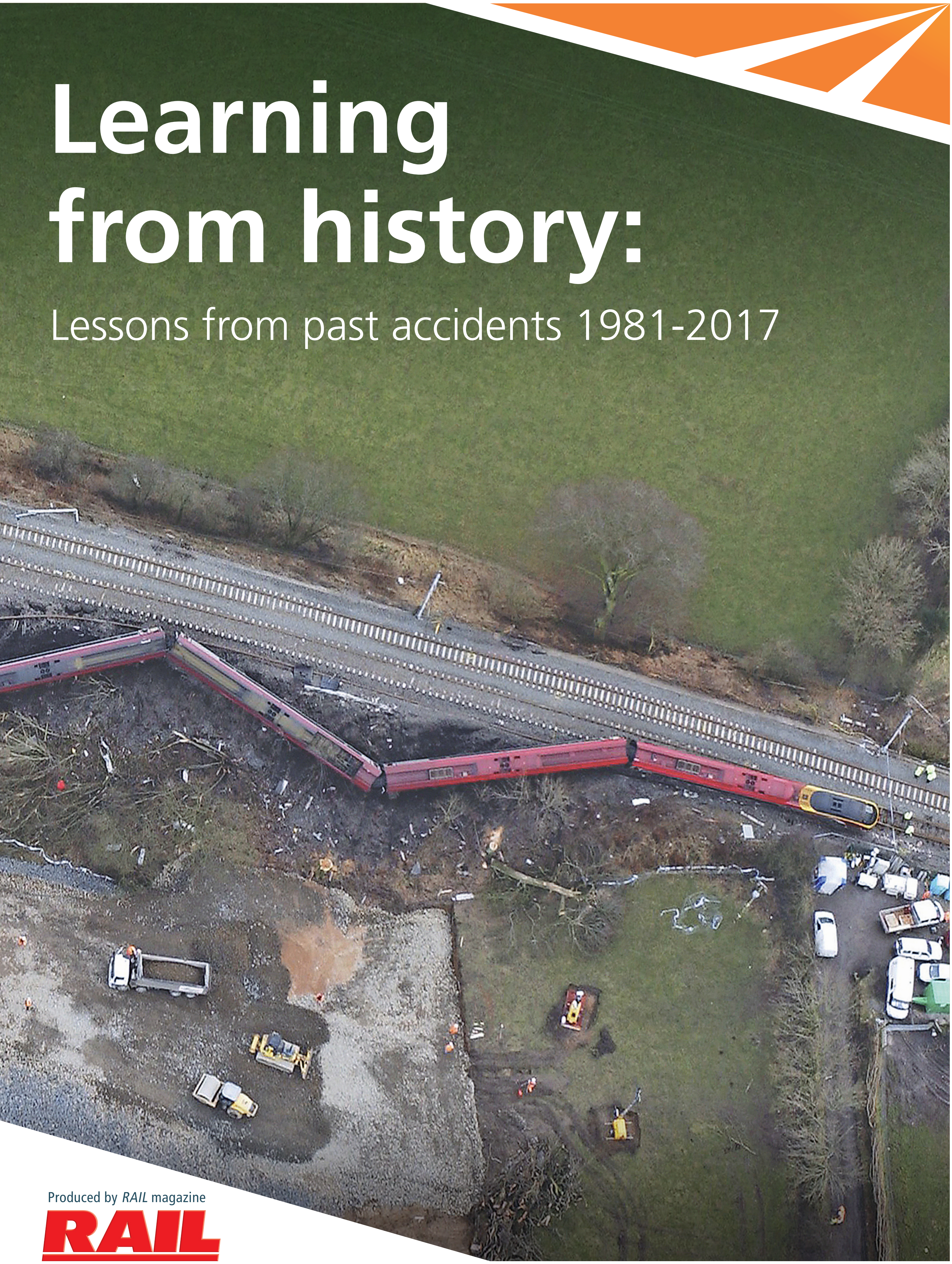
NetworkRail

Learning from history:

Lessons from past accidents 1981-2017



Produced by *RAIL* magazine

RAIL

My railway career began in 1981, and the first 26 years were punctuated by major accidents. The cycle was familiar - major accident, investigation, implementation of recommendations, repeat. Thankfully this cycle has been broken since 2007 by interventions such as Train Protection and Warning System (TPWS), and a generation of railway people have started their careers without the ever-present dark clouds of major accidents challenging society's confidence in our industry. Past generations learned a lot from accidents, and the railway people of today and tomorrow must not discard this knowledge. This booklet sets out the background and learning from the major accidents of my career, and I hope it will become essential reading for future generations, much as *Red for Danger* did for earlier generations.

It has been more than ten years since a passenger or member of the workforce has been fatally injured in a train accident on the main line rail network in Great Britain. Whilst this is a fantastic achievement, we know the potential for such low frequency, high consequence, events to occur remains ever-present. We are constantly reminded of this through the potentially high-risk events that have occurred on our domestic network in recent years, such as the derailment and collision in Watford Tunnel and serious train accidents that have occurred in other countries.

Our improving train accident risk profile can be attributed to a number of improvements that have been made over the years as we learn from earlier accidents and through intelligence gained from our assurance activities. As part of this learning process we know that thorough investigation into accidents is a vital ingredient, as is the retention of knowledge gained, known as our 'corporate memory'. As time passes, we know our people may move on to different roles so, with such low-frequency events, it remains more important than ever for our industry and its workforce to continue to remember what happened, the causal factors and what improvement actions were taken in response to the investigation recommendations.

With this in mind we have produced this booklet with the aim of reminding us all of the serious train accidents that have occurred between 1981 and 2017 and the key lessons that have been learned and then subsequently captured through improved leadership, employee engagement, engineering, rules, procedures, processes, training and equipment. We owe it to the passengers and staff killed and injured in the accidents described in this booklet to keep these lessons alive as we operate, maintain, design and build the railway of today and tomorrow.

It is this continual learning process and retention of corporate memory that helps us keep the railway safer today. Accidents are not inevitable, and with nearly two centuries of experience used wisely we can remain the safest large railway in Europe and lead the world in safety innovation.

CHRIS GIBB Non-Executive Director, Network Rail. Chairman of the Safety, Health & Environment Committee.

IMAGE: OWEN HUMPHREYS/POOL/GETTY IMAGES

The importance of corporate memory

The retention of knowledge gained as a result of accident investigation is vital...

Just before 20.15hrs on February 23 2007, a Pendolino carrying 109 passengers and crew derailed at 95mph near Grayrigg in Cumbria (pictured, left). All nine vehicles left the line; eight jack-knifed down an embankment. One person was killed - 84-year-old Margaret Masson; 28 more suffered serious injury, including the train driver.

Both the rail industry and Rail Accident Investigation Branch (RAIB) investigations confirmed that the train derailed on a crossover, the immediate cause being the condition of the pointwork. The train itself, however, was widely praised: its crashworthiness serving to minimise the harm to all those on-board.

Train accidents like this are tragedies, but they also help the rail industry to learn - investigations into them leading to recommendations, which lead in turn to actions to help stop them happening again.

The railway and its regulatory bodies have been doing this virtually 'since William Huskisson MP was struck and killed by *Rocket* at the opening of the Liverpool & Manchester Railway in 1830'. Indeed, it was early incidents like this one that 'led to the first Railway Regulation Act (1840), which required all injurious accidents to be reported to the Board of Trade'.

Within 50 years, block signalling, interlocking and continuous braking on passenger trains had been made mandatory. The 20th century saw further advancements, ranging from continuous welded rails and multi-aspect signalling, through to automatic train protection systems.

All these developments - and more - have helped the number of people killed in train accidents to fall to the extent that there have been none since Grayrigg - an unprecedented record.

The cycle of 'investigate, report, recommend, track' has both saved lives and gone some way to creating something like a 'memory'.

But, that doesn't mean learning is easy... especially not for companies. Companies comprise a number of different and disparate memories which don't always interface perfectly, and which can change as staff retire, move on, or move in from elsewhere. When you expand the idea to a complete industry like rail, it becomes even more complicated. In fact, there can be a very real danger that lessons learned in the past are forgotten and accidents repeated as a result. Two examples with similarities to recent safety events illustrate this.

Firstly, the collision at Stafford - and a number of other accidents during the 1990s - led to a 60% reduction in places where permissive working was practiced, and to the introduction of 'Huddersfield controls', which prohibit two trains moving in a section simultaneously (that is, one departing while a second enters the platform). Where the signalling does not enforce this, the signalling regulations require the signaller to do so themselves.

Furthermore, a national exercise reviewed all locations where permissive working was authorised, and withdrew it unless it was essential for operational purposes. This meant that the practice generally remained authorised for attaching, but was not widely perpetuated for platform sharing.

All these changes helped reduce the risk associated with permissive working to a point where incidents have fallen since the 1990s. Looking ahead, the greater approach speed control possible with Digital Railway's European Railway Traffic Management System (ERTMS) may allow more permissive moves to be undertaken, which may increase flexibility further by allowing more attachments to be made in stations, and so on.

But while collisions may be less common, incidents at Norwich and Plymouth in 2013 and 2016 respectively show that the inherent risk from putting two trains into one section remains.

Secondly, the industry's failure to remember the lessons of the accident at Glanrhyd Bridge in 1987 - in which a train fell into the River Towy, killing four people, after high river flow had undermined a pier - led in part to the subsidence of Lamington Viaduct in December 2015.

When RAIB released its report, Chief Inspector Simon French said that, while Glanrhyd led to 'improved procedures for checking the integrity of bridges over rivers, especially at times of flood, and more effective management of the risk of scour,' Lamington was 'a reminder that, under certain circumstances, the scouring effect of a swollen river can undermine bridge piers to the point where the structure above starts to fail'.

The vulnerability of the viaduct to scour had been identified at least ten years before, but not enough had been done about it. Only a 'rough ride' report from a driver prompted an investigation which identified the failing structure. Such a report is the last line of defence, all other engineering and procedures having failed.

'The railway has seen numerous organisational changes over recent decades,' Mr French added. 'Although change is inevitable, and often for the better, it is vital that the railway industry finds ways to retain its corporate memory of its own assets and the associated management systems.'

Through its work, the Rail Safety and Standards Board (RSSB) helps the industry retain its corporate memory. So does this booklet, which provides details of domestic, primarily catastrophic, train accidents that occurred over the period 1981 to 2017, and considers the findings of the investigations and the action taken by the industry in their stead.

KEY LEARNING

The cycle of 'investigate, report, recommend, track' has both saved lives and created something like a 'memory'.

Switches and crossings

Potters Bar, May 10 2002 / Grayrigg, February 23 2007

On May 10 2002, a Class 365 EMU derailed, killing seven people and injuring 76. The train crossed over a set of points at 97mph, which moved, causing the rear bogie of the third carriage and the whole of the fourth carriage to derail. The accident at Potters Bar was essentially about bolts and stretcher bars. One of the former had worked loose, allowing the latter to move under the passenger train.

Poor maintenance was found to be a factor, maintenance on the whole of the network being undertaken by a number of large private maintenance contractors at that time. Potters Bar contributed to Network Rail deciding to bring all track maintenance in-house from 2003 - a move that allowed the company to take a more strategic approach to the way the infrastructure is managed.

Poor maintenance was also implicated five years later, when a Class 390 Pendolino derailed on a groundframe-operated facing crossover at Grayrigg. RAIB's investigation confirmed the immediate cause to have been the condition of the stretcher bars. Between the three, one was not in position, another had nuts and bolts missing and two were fractured.

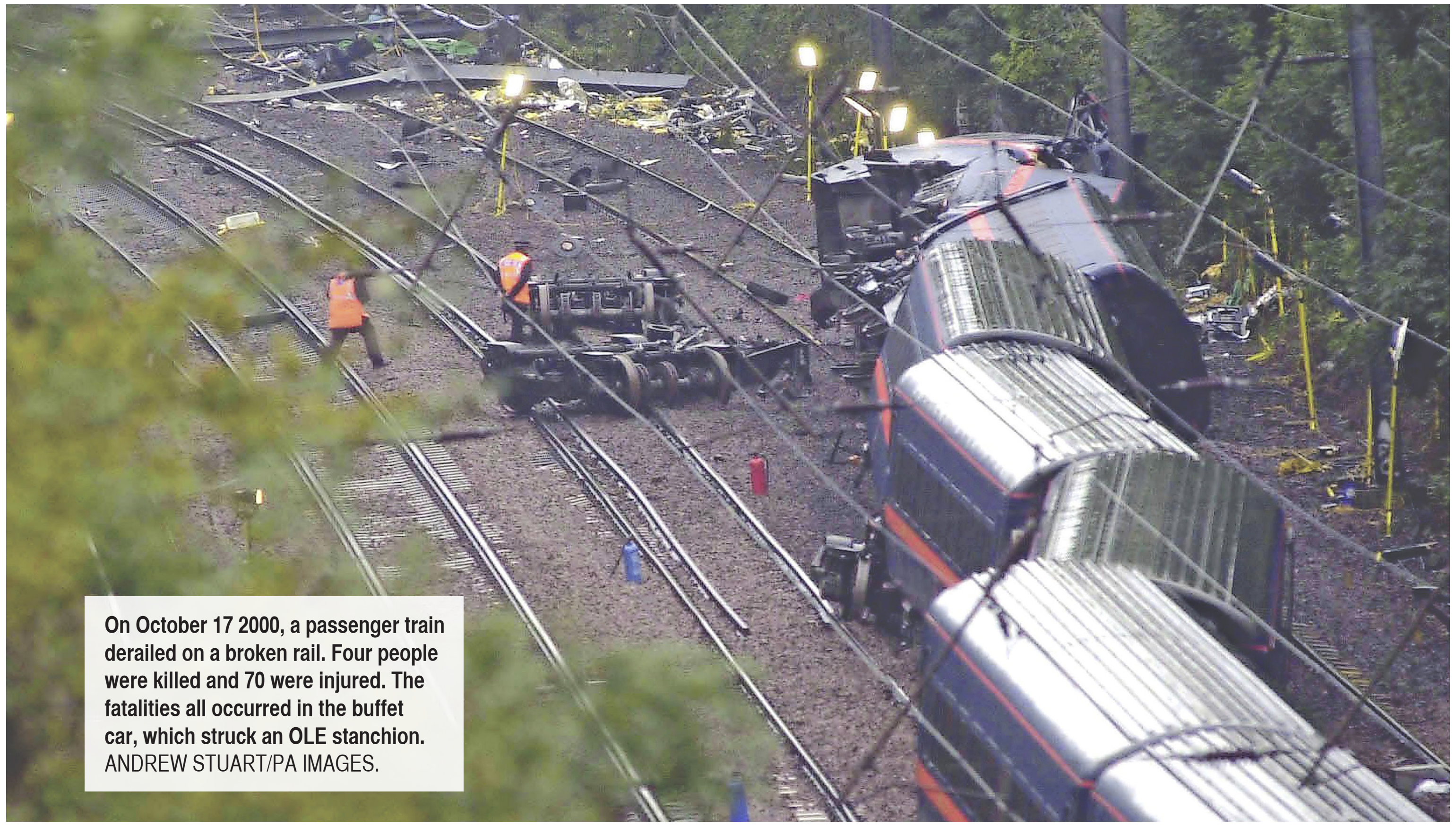
Since Potters Bar and Grayrigg, the industry has made significant progress regarding guidance and training given to staff. Improved patrolling diagrams have also been introduced which reflect the work required and associated timescales more accurately. This has been supported by more detailed measurements being taken of the track and much improved data capture within an asset data system called Ellipse.

More fundamentally, neither fixed nor adjustable stretcher bars had ever been designed with an engineering understanding of the forces to which they would be subject. Now, a new design of tubular stretcher bar - which has designed out a number of failure modes - has been introduced.

KEY LEARNING

Improved patrolling diagrams and enhanced guidance and training given to staff.

Below: During the accident at Potters Bar, the fourth carriage became detached, crossed onto the adjacent line, flipped into the air and landed in the station under the platform canopy. SEAN DEMPSEY/PA IMAGES.



On October 17 2000, a passenger train derailed on a broken rail. Four people were killed and 70 were injured. The fatalities all occurred in the buffet car, which struck an OLE stanchion. ANDREW STUART/PA IMAGES.

Broken rails

Hatfield, October 17 2000

The Hatfield accident occurred when a rail, in which gauge corner cracking (GCC) had caused multiple cracks and fractures, fragmented as a high-speed train passed over it. Ironically, the HSE and the (then) Rail Regulator had already commissioned the Transport Technology Centre to investigate broken rails and their management. The resulting report was published that November, one month after the accident. It, and the Hatfield accident itself, led to the establishment of a taskforce to research metallurgy, wheel-rail interaction, brake design, suspension design, and ultrasonic rail flaw detection.

Investigators also found, amongst other things, flaws in the training given to patrolmen, the way contractors were monitored and the way asset records were kept.

There were other factors that may have contributed, such as a post-privatisation increase in passenger and freight traffic, which put great strains on the 'stretched, ageing and fragile' infrastructure. Furthermore, the RSSB/Railway Safety investigation report noted that the GCC at Hatfield's root took Railtrack - and everyone else - by surprise. In fact, the phenomenon was first noticed in the early days of diesel traction, when heavily-laden wheelsets revolving at high speeds were found to 'flake' the railheads. Instances were few at first, but started to become more prevalent on the West Coast Main Line in the 1980s. This led to a series of reports in the 90s that showed GCC to be playing an increasing role in defects and broken rails. There was increasing awareness too that high curve rail positions were more vulnerable to damage than others. When an increase in the manufacturing hardness of rails is added to changes to the wheel profile that meant the same section of rail was being used all the time, an accident was much more likely.

As a response to Hatfield, the industry now has a much better understanding of rail failure modes and how to manage them better through, for example, rail grinding. The technology in this area has also improved and includes the introduction of Plain Line Pattern Recognition (PLPR) and ultrasonics, combined with eddy current testing, capturing a much more accurate picture of the condition of rail in situ. Network Rail has also introduced a number of predictive tools and programmes to identify precursor events and help the track engineer with the prevention of rail defects.

In addition, the installation of 'Gotcha' lineside equipment detects real-time vehicle wheel imbalance and impact loads on the rail, which allows rail vehicles with these defects to be stopped, thereby reducing damage to the track.

Thanks to these measures, broken rails have fallen from a 40-year average of 750 a year to an eight-year average of around 150.

KEY LEARNING

New technology can now capture a more accurate picture of the condition of rail and predictive tools identify precursor events.

NetworkRail

On December 12 1988, 35 people were killed and 484 were injured (69 seriously), following a multi-train collision at Clapham Junction. A crowded train crashed into the rear of a stationary one, resulting in a derailment which was struck by an empty train travelling in the opposite direction. PA IMAGES.

Wrong side failures

Clapham Junction, December 12 1988

Of all the accidents reviewed in this booklet, the catastrophic incident at Clapham Junction more than any other came from a culture of complacency towards safety at the time. As the inquiry report records: 'the appearance of a proper regard for safety was not the reality. Working practices, supervision of staff, the testing of new works…failed to live up to the concept of safety. They were not safe, they were the opposite'.

The accident occurred because a train passed a newly installed signal that was showing 'green' when the section ahead was occupied. The debris created by the resulting rear-end collision was then struck by an empty train travelling in the opposite direction.

The immediate cause of the wrong side signal failure was a series of errors by a signalling technician, who had installed new wiring within a relay room as part of re-signalling works, but left old wiring in place and unsecured. This had been disturbed during unrelated work the day before the accident. The inquiry report records that this was a combination of 'characteristic errors' of poor working practices that should have been picked up by proper supervision and 'uncharacteristic errors' that had arisen from constant, repetitive work and excessive levels of overtime that had 'blunted his working edge'.

As a result, new processes and instructions were introduced relating to the installation and testing of signalling works, including the development of the Signalling Maintenance Testing Handbook (SMTH) and a Signalling Works Testing Handbook (SWTH).

Among the report's many recommendations was one to 'ensure that overtime is monitored so that no individual is working excessive levels of overtime'. This led to criteria being developed of what was considered acceptable levels of working (known as 'Hidden 18') and a process to monitor it. The latter is currently being refined further with the development of a new standard on managing the risk from fatigue.

KEY LEARNING

New processes and instructions were introduced relating to the installation and testing of signalling works.

Clapham Junction Inquiry report

Signals Passed at Danger (SPADs)

Colwich Junction, September 19 1986 / Purley, March 4 1989 / Newton, July 12 1991 / Severn Tunnel, December 7 1991 / Cowden, October 15 1994 / Watford, August 8 1996 Southall, September 19 1997 / Ladbroke Grove, October 5 1999

The signalling system is designed to ensure that trains are kept a safe distance apart, a 'red' meaning either that the section ahead is occupied or a conflicting route has been set. Passing a signal at danger - having a 'SPAD' - is a major train accident precursor, a fact demonstrated by the 54 people who lost their lives and the thousand or more who were injured in the incidents listed above. Clearly, when a driver fails to stop at a danger signal - for whatever reason - the results can be catastrophic.

Technology to help mitigate the risk began on the Great Western Railway as early as 1906, its Automatic Train Control equipment eventually being superseded by BR's Automatic Warning System (AWS) from the 1950s and the widespread adoption of multi-aspect colour light signals from the following decade. None of these physically prevented a train from passing a signal at danger, however.

By the 1980s, some European railways had begun to introduce Automatic Train Protection (ATP), a system that did automatically control the speed of a train to stop at a signal at danger. Virtually all the investigation reports into the incidents above note that ATP would have prevented the accident from occurring and, up until Watford in 1996, made (or supported) recommendations that ATP should be introduced, as a minimum, to high-speed and intensively-used lines. Yet ATP was an expensive and complex option and, although two trials were introduced from the early 1990s on the Great Western Main Line out of Paddington and the Chiltern lines from Marylebone, alternative, quicker to implement and more cost-effective solutions were explored, leading to the development of the Train Protection and Warning System (TPWS) by the end of the decade.

Following the two accidents at Southall (1997) and Ladbroke Grove (1999), the respective inquiry chairmen published a joint report into train protection systems. It supported the 'currently accelerated programme' for the fitment of TPWS, but noted that 'its benefits are plainly limited and, despite the substantial expenditure that it represents, TPWS will still permit a proportion of ATP-preventable accidents to occur'.

It is clear that the authors of the report saw TPWS as an interim 'better-than-nothing' solution, pending the introduction of the European Train Control System (ETCS) that provides ATP functionality, which they anticipated being rolled out from 2008, initially as part of the modernisation of the West Coast Main Line.

At the time, concerns over TPWS mainly related to its perceived lack of effectiveness at speeds over 70mph, but the system has been developed further since with the introduction of TPWS+ to take account of the initial constraints. The last SPAD where a train reached the potential conflict point on a high-speed line, where TPWS was fully operable on both track and train, was at Didcot North Junction in November 2007. Here, however, TPWS+ had not been fitted, despite previous risk assessments demonstrating that the existing configuration of TPWS had only limited effectiveness at the location.

TPWS is now a well-established and effective form of SPAD mitigation, fitted at signals in accordance with risk-based criteria and also prevents buffer stop collisions and overspeeding. But with ETCS yet to be introduced, the industry TPWS Steering Group is continuing to consider whether TPWS installation has reduced risk as far as is reasonably practicable.

Alongside the technical solutions designed to reduce the consequences of SPADs, the industry has taken significant steps towards a better understanding of the human behaviours that can result in a driver failing to stop at a red. As recently as the Purley SPAD of 1989, it was apparent that many thought the driver was solely responsible, despite it later (in 2007) being concluded that there was 'something about the infrastructure of this particular junction [that] was causing mistakes to be made'. This tendency to blame the driver for a SPAD meant that many latent failings regarding sighting and reading of some signals regularly passed at danger were not adequately considered in the investigation - an oversight that contributed to the tragedy at Ladbroke Grove in 1999.

Managing SPAD risk and mitigation has been one of the industry's major success stories since 2000. There is now a much better understanding of how drivers can perceive and sometimes misinterpret signals, factors which - like the risk from signal overruns - are now considered at the design stage. The introduction of LEDs has greatly enhanced the conspicuousness of many signals, while a greater emphasis on driver training is now apparent, with initiatives such as defensive driving and risk-triggered commentary having come on stream.

That said, it is recognised that TPWS is vulnerable to misuse, with occasional instances of 'reset and continue' (where a TPWS intervention brings a train to a stand, but the driver resets and continues without speaking to the signaller) or of the driver isolating the on-board equipment. The latter led to a steam-hauled passenger train reaching the conflict point moments after a high speed train had passed at Wootton Bassett Junction in March 2015.

The industry has agreed the need to develop a strategy for the continued risk management of SPADs over the next decade, covering the period before the widespread installation of ERTMS is expected, but proportionate to the risks SPADs present. The strategy is being developed by considering the ongoing need for mitigations in the short, medium and long term, while recognising existing good practice and making the case for new controls for the future.

KEY LEARNING

Had TPWS been applied historically, around half of the accidents and deaths in this booklet would have been avoided.

Level crossings

Ufton Nervet, November 6 2004

Trains striking vehicles on level crossings are relatively frequent, occurring around two-to-three times a year, one of the most recent being on January 3 2017 at Marston Automatic Half Barrier (AHB) crossing. The car driver was killed, but - as is often the case - the train remained upright and did not derail and there were no reported injuries to anyone on board.

At Ufton Nervet, a car was deliberately driven onto the level crossing by a suicidal motorist. In this case, the impact with an HST did result in the leading wheelset of the train derailing. Normally, the train would have braked to a stand, but less than 100 metres ahead was a set of points leading to a loop line. The derailed wheelset started to turn towards this loop, causing the train's leading vehicles to overturn.

Following RSSB's report into the accident, the industry's level crossing risk assessment process, ALCRM (the All Level Crossing Risk Model) was enhanced to include the consideration of post-collision potential at each level crossing. In the event of a crossing being identified as high risk, this allowed more options for risk mitigation.

Although the crashworthiness of the Mk 3 coaches was noted, the relatively high number of fatalities (seven people) was found to be partly due to passengers being ejected through windows that pre-dated the requirement for safety glass to be installed on railway vehicles. Recommendations were made to address this.

The report recommended that a programme of research be pursued to assess the benefits and practicalities of installing seat belts in passenger vehicles. RSSB's research concluded that the advantages in the fitting of seat belts in reducing the likelihood of ejection from the train were more than outweighed by the possibility of a person becoming trapped by a loss of survival space in the event of damage and structural intrusion. The seat reinforcement required for fitment would also increase injury potential for occupants who, for whatever reason, were un-belted - that is they would have something harder to strike against.

Ufton Nervet level crossing was closed on December 16 2016 after a new £7 million road bridge was built to provide a safer crossing. NETWORK RAIL.

Animals

Polmont, July 30 1984

The accident at Polmont was another where, while the event - train strikes one or more large-boned animals - was, and is, not uncommon, the potential multi-fatality consequences had not been considered since the introduction of higher-speed push-pull operations in 1967.

By the mid-80s, British Rail was operating a number of 'push-pull' express passenger services, with plans for many more. The investigation report on Polmont concluded that the concept was 'acceptably safe', but noted that the leading vehicle in that particular case had certain characteristics that contributed to the derailment, particularly a low axle weight, which caused it to rise over the obstruction.

Subsequently, obstacle deflectors were fitted to the leading vehicles of all trains with an axle load of less than 16 tonnes.

Other recommendations covered improvements to fencing where livestock was adjacent to the line, the provision of headlights on all trains, amendments to the rules regarding the reporting of large animals within the railway boundary and the provision of radios in all trains operated at 100mph or more. All were addressed by British Rail.

Following an accident in Germany in January 2012, in which a passenger was killed when a push-pull train running in 'push mode' derailed after striking a herd of cattle, RSSB produced a report providing risk and performance data relating to 'animal on the line' incidents in Great Britain.

It also reassessed the lessons learned from Polmont, adding that 'subsequent improvements in these areas explain why the risk from post-animal strike derailment is now very low'.

However, low risk does not mean incidents will not occur, as the collision and derailment at Godmersham (July 2015) shows.

KEY LEARNING

The risk from post-animal strike derailment is now very low, due to improved fencing and lineside inspection.

On February 28 2001, an express train struck a road vehicle that had crashed onto the line at Great Heck. The derailed train was deflected at points into the path of a freight train. Ten people were killed and 82 were injured in the resulting collision. OWEN HUMPHREYS/PA IMAGES.

Road vehicle incursions

Great Heck, February 28 2001 / Copmanthorpe, September 25 2006 / Oxshott, November 5 2010

The accident at Great Heck occurred after the driver of a Land Rover towing a loaded trailer fell asleep whilst driving along the M62. The vehicle swerved off the motorway, down an embankment and onto the East Coast Main Line. After failing to reverse his vehicle off the line, the driver left it and called the emergency services moments before it was struck by a train. As in the incident at Ufton, at first only the front bogie derailed, the train remaining upright for around half a mile before points to nearby sidings diverted it into the path of a freight train carrying coal.

The investigation found no failings 'in respect of health and safety legislation by the railway infrastructure controller or the train operators', but recommended that 'The Department for Transport, Local Government and the Regions (DTLR) [...] lead, with the involvement of relevant interested parties, the development of tools and data for use at local level by highway and railway professionals to carry out comparative assessments of the risks of road vehicles obstructing the railway at specific sites.'

This exercise was carried out nationally, with mitigation introduced at locations according to the risk identified.

Five years later, a few miles north of Great Heck at Copmanthorpe, a car also drove onto the East Coast Main Line. A northbound Super Voyager train running at 100mph collided with it and derailed, this time remaining upright and causing no on-board injuries.

The investigation noted that the road on which the car driver approached the railway was a cul-de-sac with a simple boundary wooden fence.

Twenty years earlier it had been a level crossing, but had not been included in the risk assessment of road vehicles although the road that ran parallel on the other side of the line had been. Subsequent to this accident, the guidelines for assessment were amended to include similar cul-de-sacs. The car driver was killed, and the investigation was unable to establish why the car was driven onto the railway.

The investigation concluded that the design of the train, to modern standards, and in particular the obstacle deflector, played a significant part in the derailed train coming to a halt without any injuries to the passengers and crew.

Road vehicle incursions are still a feature on Network Rail-managed infrastructure and, given the proximity of many roads to railway lines, they are likely to remain a risk. The potential consequences of a derailment arising from a collision at locations where it is possible for a car to access the railway should however be mitigated by a hierarchy of defences proportionate to the risk of a vehicle incursion.

An event unique in the history of railways occurred just north of Oxshott station in Surrey, when a loaded cement mixer collided with a road-over-rail bridge's parapet which collapsed, with the lorry falling onto a passenger train that had just departed the station. Seven people were injured, two seriously, including the driver of the lorry.

Recommendations were focused around providing guidance on better highlighting safety hazards on railway bridges and for structural inspections and examinations to identify and record any highway features which may increase the risk to the railway.

Earthworks & structures

Ais Gill, January 31 1995

The accident at Ais Gill was relatively minor at first, occurring after a train ran into a landslide and derailed.

It escalated when the respective control offices failed to respond correctly to the emergency National Radio Network (NRN) call that the injured driver was able to send immediately after the derailment.

At the time the incident occurred, a service approaching on the opposite line was still seven minutes away. Owing to a lack of adequate training and equipment, no emergency call was made to the driver of this second train. As a result, it struck the derailed train, killing its conductor, who had focused on the welfare of his passengers, rather than fulfilling his duties by providing detonator protection against approaching trains.

Regarding the landslide, the investigation noted only that the area had no history of them and that there had been no sign of one when the line had been inspected earlier that day. It focused instead on the deficiencies with the communication system and its application.

Ais Gill is the last fatality on the GB mainline network to arise from an earthworks failure, although there have been a number of instances of trains striking landslides or rockfalls and derailing, some of which, notably Watford Tunnel (2016) and Falls of Cruachan (2010) could very easily have resulted in much more serious consequences had their circumstances been slightly different.

Since 1995, radio and telephone technology has advanced dramatically and GSM-R has become standard. The latter allows communication directly between driver and controlling signaller, thereby affording a much faster and more targeted response. It should be noted, however, that there was an incident involving a train striking several cows at Godmersham in July 2015, where damage sustained in the collision resulted in the failure of the equipment.

Again technological developments have allowed the development and trial installation of remote monitoring equipment designed to detect movement that could result in an earthworks failure.

In addition, the management of train operations during times of extreme weather, particularly the imposition of speed restrictions, has significantly improved in recent years, thus helping reduce the associated collision risk.

The devastation near Ais Gill following the collision between two Class 156 units on the Settle and Carlisle Line. MALCOLM STEAD.

Glanrhyd Bridge, October 19 1987

In 1987, Glanrhyd Bridge partially collapsed as a result of the River Towy swelling after many hours of heavy rainfall. The previous evening, adverse weather conditions had led to a number of reports of flooding and potential ballast wash-out on the Central Wales Line, but attempts to inspect the track visually were thwarted by local roads being blocked by those same floods. It was duly agreed that the first train in the morning would be used to examine the line.

The driver was accompanied by a permanent way supervisor. His train had negotiated its way through a number of flooded locations when it proceeded onto Glanrhyd Bridge at 10mph. Darkness made it impossible to see that part of the bridge had washed away; consequently, the front half of the unit ran onto the unsupported section before falling into the river, which had almost reached track level by this time.

Before Glanrhyd Bridge, the Rule Book allowed passenger trains to be used for line examinations over structures that may have been damaged. After the accident, trains were not permitted to pass over a structure until it had been examined by a competent person, although this has subsequently been relaxed in some locations on a risk assessment basis.

The investigation report highlighted a 'lack of understanding' amongst railway engineers about the 'complex behaviour of watercourses' and, while improvements have been made, events can still occur that show a comprehensive understanding of the effects of rivers and tides to be lacking.

The situation is now being addressed via a new Code of Practice for coastal, estuarine and river defences, and the sharing of best practice risk assessment methodology, weather alerts, monitoring technology and adverse weather response arrangements.

On October 19 1987 the 0527 Swansea-Shrewsbury Class 108 DMU tumbled into the River Towy near Llandeilo after the Glanrhyd Bridge was partially washed away. Four people died. PA IMAGES.

Infrastructure operations

Seer Green, December 11 1981 / Stafford, August 4 1990

These accidents resulted from errors made initially by either the signaller or train driver, resulting in a collision.

At Seer Green, a signaller talked a train past a signal at danger into a section occupied by a train after misreading their signalling diagram and believing the section to be clear. The first train had stopped out of course in heavy snow to clear branches from the line. At Morpeth, the signaller talked a second train past a 'red' into an occupied section, mistakenly believing he was talking to the driver of the first train.

The circumstances at Stafford were different in that the driver had been signalled legitimately, if not ideally, into an occupied platform under permissive working, but failed to slow the train sufficiently.

The driver, who died in the collision, was subsequently found to have worked excessively long hours and had high levels of alcohol in his system.

After Seer Green, the rules governing the speed of trains when travelling cautiously through sections were amended and a new instruction that 'the driver must always be able to stop within the distance he can see the line to be clear' was introduced. Subsequent events - particularly involving engineering trains travelling within possessions - have resulted in further work to redefine travelling at caution or not under the protection of fixed signalling.

Following Stafford, a greater emphasis was placed on the implementation of monitoring procedures to restrict working hours. Statutory standards relating to drink and drugs for safety critical staff were also introduced by British Rail in January 1992.

KEY LEARNING

Designing out the potential for a single human error that can lead to disaster is a top priority.

Moreton-on-Lugg, January 16 2010

The collision at Moreton-on-Lugg crossing was caused by the signaller becoming distracted by a work-related telephone call and mistakenly raising the barriers before a train had passed. That train struck two cars, resulting in the death of a passenger in one of them.

RAIB was critical of the lack of any engineered safeguards at the location, and potentially elsewhere. As a result, approach control was introduced at a number of level crossings in order to prevent a similar type of occurrence.

The subject of human error resulting in train accidents was covered in more detail in a Network Rail paper in November 2016, which noted that 'the risk due to human operator error still is one of the largest components of train accident risk, particularly in degraded operational conditions or circumstances that are out of course'.

Several hundred user-worked crossings (UWCs) remain in use that depend on signaller-user communications for their safe operation. When this is not effective, there can be an accident, as occurred at Hockham Road in April 2016, when a train struck a tractor on the crossing.

These risks are managed primarily, with regard to signallers, 'through regular competence assessment and assurance provided through supervision and observation of the task'. A Network Rail action plan looking at all aspects of signaller competence is currently in progress, and includes reviewing best practice from industry research; benchmarking with other industries; forming level crossing action plans; improving safety critical communications; increasing the use of simulators; improving levels of assurance; and improving continuous development and non-technical skills.

NetworkRail

Buffer stop collisions

Cannon Street, January 8 1991

The accident at Cannon Street station occurred because the driver of an incoming train failed to control its speed sufficiently to bring it to a stand short of the buffer stops. The high number of injuries that resulted was compounded by an overcrowded train and the relative lack of crashworthiness of the ageing rolling stock.

The investigation report identified that 'drivers are permitted to enter terminal platforms at too high a speed [which] significantly reduces the chances of a driver being able to take the action necessary to recover from an error of judgement and avoid the collision'.

Furthermore, it was 'essential that the final speed of approach of the train towards the intended stopping point is limited to the maximum speed which the buffer stop will absorb without the impact causing serious or widespread injury'.

To address this latter point, current Railway Group Standards require new buffer stops to be of an energy-absorbing design, with existing stops for terminal or bay platforms requiring a current, documented, assessment of the risk arising from a train collision with them. TPWS is additionally provided to prevent a driver from approaching buffer stops too fast.

The report also noted that the driver had been tested for drugs three days after the accident. Traces of cannabis had been found in his system, although the public inquiry found that there was insufficient evidence to prove drug use had been a factor.

Nevertheless, the accident led to legislation that made it an offence for railway employees with safety responsibilities to be impaired by the consumption of alcohol or drugs. This came into force under the Transport and Works Act 1992.

Regarding the rolling stock, Cannon Street showed the Mk 1-based and Southern Railway-designed EMUs involved to be inherently uncrashworthy.

The report recommended their early withdrawal and replacement. The Southern-designed stock had been withdrawn by 1995. Mk 1 trains finally left the main line network ten years later.

KEY LEARNING

New buffer stops are required to be of an energy-absorbing design and assessed for the risk arising from a train colliding with them.

On January 8 1991 a Class 415/416 train of ten carriages collided with the buffer stop at Cannon Street. The fifth and sixth carriages crushed into each other. Two people were killed and 542 injured. REBECCA NADEN/PA IMAGES.

One of the new Class 800s that is being introduced onto the East Coast Main Line and Great Western Main Line as part of the Intercity Express Programme. IAN COPPLESTONE.

Improvements to rolling stock

Design, technology and better communication...

In addition to the improvements in controls that reduce the likelihood of an accident, there has been similar progress in improving the crashworthiness and other aspects of rolling stock and locomotives that has the effect of reducing the likelihood and severity of injuries in the event of an accident.

Most passenger train coaches are now of the more robust monocoque design which has improved crashworthiness with windows fitted with safety glass, which provide much better protection in the event of an accident and fewer casualties compared to earlier designs.

There are also safety requirements for the internal design of new trains, such as seating and tables to reduce injury in the event of a collision or derailment.

The influence of this could be seen at Grayrigg, where the path of the leading vehicle would almost certainly have led to more fatalities had it been from an earlier generation of rolling stock.

The design and construction of seating, vehicle ends, couplers, materials, brakes, engines, electrical and fire detection and suppression systems and bogies have also advanced in recent years, improving safety of day-to-day operations.

Modern technology and telecommunications now allow direct and effective communication between a train driver and signaller, which was a key recommendation in many of the investigation reports reviewed here, including that for Polmont.

KEY LEARNING

Improved crashworthiness, windows fitted with safety glass and new requirements for internal design.

NetworkRail

Conclusions

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Reviewing accident reports over the 1981 - 2017 period reveals the evolution in the development of understanding of accidents and the means to prevent them from occurring. This evolution builds on that of previous years which LTC Rolt illustrates to great effect in his work *Red for Danger: The classic history of British railway disasters*.

In the earlier reports contained within this booklet, it is evident that there is a tendency to blame an individual for their failings and not take account of the factors that could have led to a person making a mistake. As time progresses, the concept of human factors is introduced, which allows the industry to understand better any latent conditions that can have an influence on people's actions. This has led to improvements in staff training and assessment, and the introduction of initiatives like defensive driving.

The earlier reports also feature a consistent echo that ATP and radio communication between the driver and signaller would have prevented this accident. It is possible to discern an increasing, almost frustrated tone in the repetition of recommendations covering these elements. Now the industry has both, though the former currently features TPWS rather than the then costly, complex and slow to introduce ATP. Had they been applied historically, around half of the train accidents and deaths considered within this document would have been avoided.

The industry's Digital Railway vision will enable full ATP to replace TPWS, giving substantial benefits across all aspects of railway operations and customer experience.

The understanding of risk and its application in providing targeted, proportionate mitigation has also developed significantly over the same timeframe. From its initial use in relation to signals and level crossings, it is now being applied to other assets and operational scenarios.

Accordingly, reading many of the reports discussed in this document it is difficult to envisage an accident arising from similar causes. Reviews undertaken on current investigations do however identify existing control weaknesses that are reflected in some of the more historic events, particularly regarding the competence, knowledge and understanding of staff.

In undertaking this review, it is apparent that the key learning from these accidents is not readily available other than in specialist railway/safety publications or through research on the internet. Whilst some knowledge will be maintained within certain people's minds, either due to relevance to their role or their past experiences within the rail industry, there is no collective knowledge in a single repository.

The memory of the lessons that have been learnt from these accidents have been translated into improved engineering, rules, procedures, processes, training and equipment that is in use today. Yet if the reason for these improved safety controls is lost from our collective memories then these controls may get eroded.

This booklet is made available so that engineers, managers and the frontline workforce can better understand the reasons for these controls and be more aware of their role in preventing future accidents.

KEY LEARNING

A relentless focus on elimination of factors that influence staff to make errors, is essential in improving safety.

IMAGE: NETWORK RAIL

Recommended further reading:

- Rolt, LTC. *Red for Danger, The Clasic History of British Railway Distasters*. History Press, 2009.
- Reason, James. *Managing the risks of organisational accidents*. Ashgate, 1997.
- Faith, Nicholas. *Derail: Why Trains Crash*. Channel 4 Books, 2000.
- Hall, Stanley. *Railway Detectives: The 150-Year Saga of the Railway Inspectorate*. Ian Allan, 1990.
- Hall, Stanley. *Beyond Hidden Dangers: Railway Safety into the 21st Century*. Ian Allan, 2003.
- RSSB's *Learning from operational experience* resources.
- Rail Accident Investigation Branch archive of reports and other materials.

On February 23 2007 a passenger died when a Virgin Trains Pendolino derailed at 90mph near Grayrigg (Cumbria). The accident was blamed on poorly maintained pointwork. The railway has learned many important lessons from the incident. RAIB.