Provide a Safe and Efficient Method to Enable Non-destructive Testing of Hidden Metallic Standalone Column

What is the situation?

Network Rail's headline Business Critical Rules are 'Loss of safe environment' and 'Objects falling from height leading to injury'. These incidents occur at least once a period.

Following a spate of lighting columns failures an additional round of surveys were undertaken in 2015/16.

The findings showed that visual inspections are sufficiently robust so as to identify non-examined or hidden elements, but they do not address the necessary follow up explorations. Currently, these activities are undertaken through excavation and exposure of the hidden part.

fig. 1

fig. 2

Typical hidden inspection issues include, but are not limited to;

- Poor visibility and generally a lack of detail.
- Defect can not been seen.
- Limited ways to apply a condition marking index based on quantitative measures.

The problems with access solutions are:

- Volume of columns. i.e. 70,000 of them to inspect.
- Prioritisation.
- Control of additional paraphernalia that are added to the columns, i.e. signage, PA systems, plant pots.
- Undertaken in operational station environment.

fig. 3

Priority problems

Specific priority problems

- Safe methodology to ascertain appropriate condition data of lighting columns to reduce safety risks for the workforce and the public.
- To enable short, medium and long term asset management decisions through accurate data analysis and intelligence.

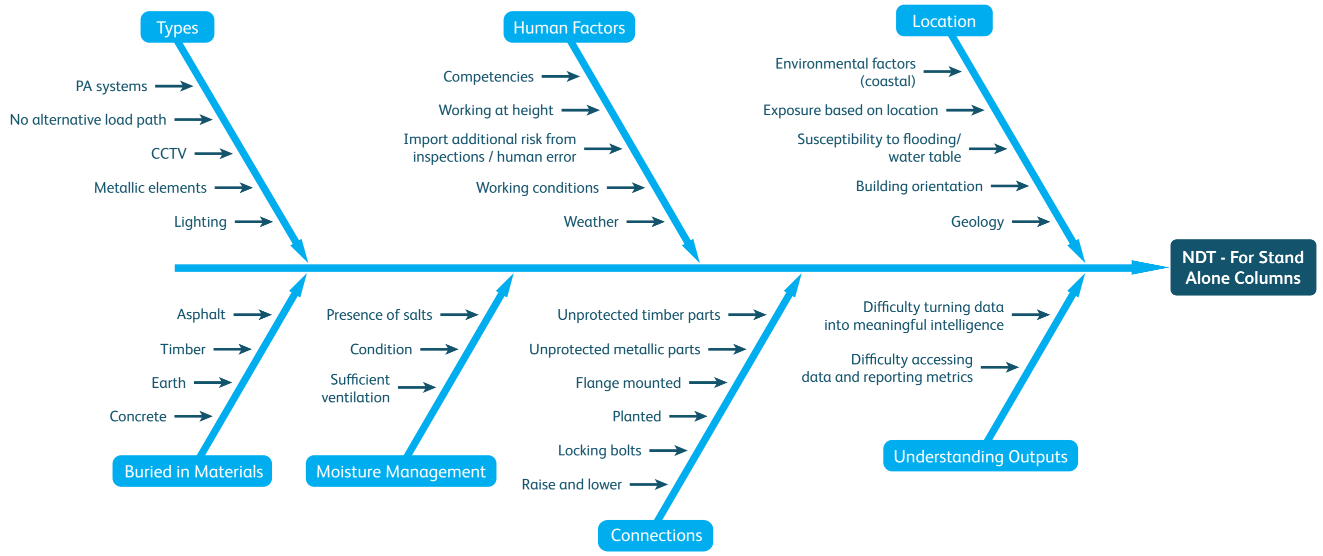
Related goals

- To inspect 50 % of assets with automated technology by CP7.
- To access all assets in order to collect the service and structural condition; whether physically or remotely by CP7.

Benefits

- Safe and efficient inspections / monitoring activities will help to complete the asset inventory and capture the status of the asset.
- Timely and effective inspections will help to reduce the number of failures thus improving the safety of the network.

Analysis of causes



Specific research needs

The research needs to consider:

- Difficulty to inspect and to detect cracks, movement and deflection.
- How to inspect the hidden and inaccessible parts.
- How to inspect while a station is operational and in daylight.
- How to communicate the findings effectively to both technical experts and laypersons.
- A predictive tool to specify an ongoing risk based inspection regime.

To address these challenges it is expected that R&D actions will need to address the following aspects:

Lack of safe methodologies to inspect

- Remote condition monitoring and early warning detection of asset failure is required for lighting columns. How can we identify what is normal and abnormal within lighting columns?
- How do other asset owners monitor their assets? Can we adopt any effective methods or techniques from other industries?
- What are the common failure modes for particular material types? What are the risks for these failure modes?
- Are there remote (hands off proxy) methods for collecting data? Is there something already available in other industries that we can implement?

Insufficient decision support tools

- How do we implement an asset risk register relating to extreme weather; based on location, asset condition and criticality?
- How can the findings be easily and clearly communicated to surveyors and Asset Engineers and give time-framed action recommendations?
- How can both new and current processes be managed better with decision support tools? What is required to develop a live bottom-up work-bank tool and how would this integrate with existing systems? How can intervention scenarios be modelled in order to support business planning?

Output Vision

- An inspection methodology and reporting solution that will allow Network Rail to fully understand the condition of its lighting columns with maximum safety, minimum cost and minimum disruption. The output should enable surveyors and Asset Engineers to clearly and easily understand the condition and enable them to make time framed decisions.

Self-maintaining Materials

What is the situation?

Network Rail owns a wide variety of buildings and structures that are in an ageing state, in need of regular remediation works to keep them in use.

As the assets weather over time, the structural capability can decrease as the materials corrode. In order to counter this, repairs are carried out to ensure that the existing structure stays in its serviceable state and allow the railway to continue performing.

At present there is an increasing demand for the use of these assets and a reduction in the availability of access to maintain these buildings. Although current repair methods are satisfactory and meet the requirements, there is a need to review the way in which we attempt these repairs in order to meet the demands of the future.

The future railway shows an increased capacity with an ever reducing opportunity for possessions and therefore access to the railway for repairs and maintenance. As the working dynamic changes, we must adapt our approach with more innovative ways in which we, as a company, can develop our processes to match this changing landscape.

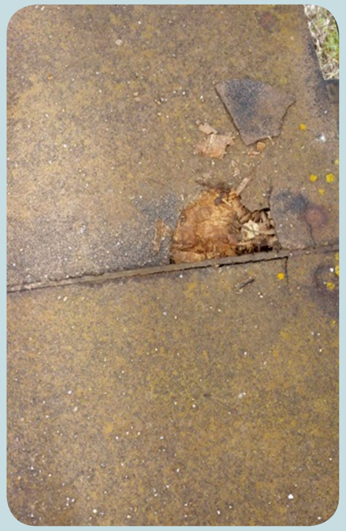


fig. 1

fig. 2

fig. 3

Priority problems

Specific priority problems

- Cracking in materials which degrade the structural capacity of the critical assets.
- Engineers are given less access time to repair structures and buildings.
- People are put in danger by working lineside or at height.
- Faults in surfaces are the largest problem area that Network Rail faces at present.

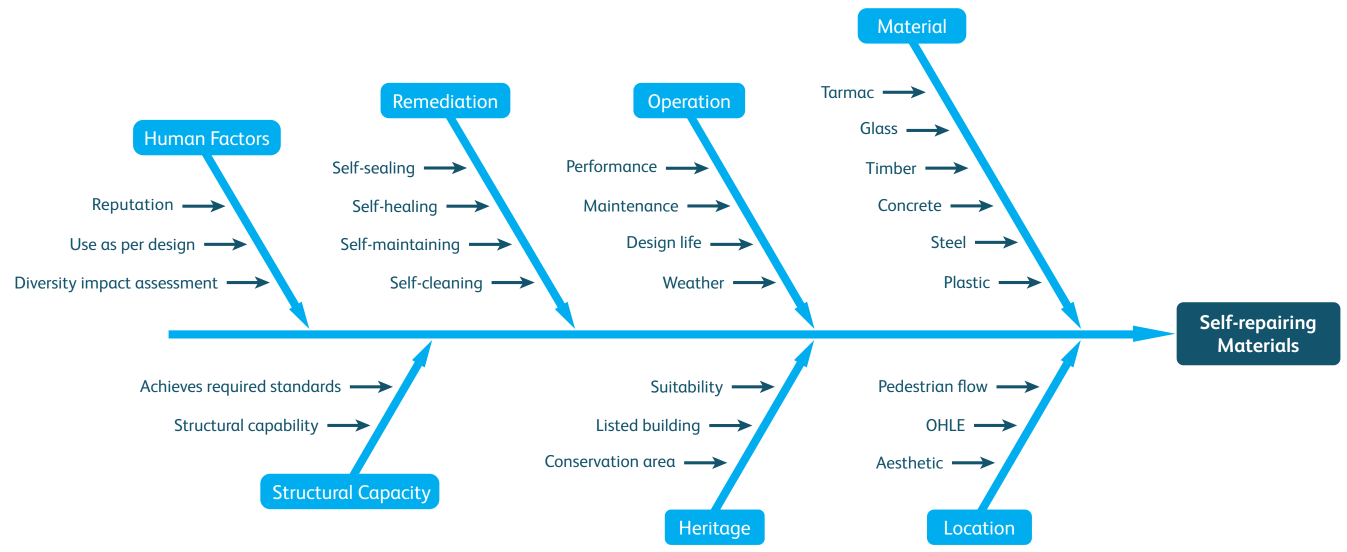
Related goals

- Reduce the number of repairs that require engineer intervention.
- Reduce the materials needed for repairs.
- Reduce the time and effort required to repair assets.

Benefits

- Reduce the amount of time internal structural elements are exposed.
- Reduction in volume of material created, therefore environmental benefit.
- Increase in time between repairs.
- Reduction in material cost for repairs.
- Reduction in working time on repairs.

Analysis of causes



Scope

The scope is to create and demonstrate the use of materials that can be implemented safely within the buildings and architecture portfolio, by non-specialised workers, which will maintain or improve the structural capacity and/or the serviceable state of the building, whilst having the ability to repair itself without the need for intervention or remediation works.

The new repair methods should allow for a similar or reduced volume of materials required whilst maintaining the same structural capacity.

Within Network Rail there are many assets that are gradually reaching their life expiry and there is a real appetite to explore any technologies which could be retrofitted to allow the assets to self-maintain, bringing them into the 21st Century.

Specific research needs

To address these challenges it is expected that R&D actions will need to address the following aspects:

- What innovative material solutions can be provided in order to reduce the need for preventative remediation works to take place on structures? And how this can be applied to the existing infrastructure?
- The research should look into different materials, and how each of them can be maintained or healed without the need for intervention.
  1. Concrete – beams that support loads with cracks in them.
  2. Timber – cracking timber struts.
  3. Platform surfaces – cracked/pot holed tarmacked surfaces.
  4. Steel – exposed steel columns.
- What are the repair solutions for the various different proposals and how strong will these be post self-repair?
- Is there a retrofit piece of technology to go on our existing infrastructure that would be able to implement the self-maintaining infrastructure to increase the asset life?
- Explore the various materials and how they can be self-cleaned at a variety of angles and inclinations without extra work required.

Transferring Customers Across Tracks

What is the situation?

Network Rail is a safety critical company and prides itself on focussing on the customer and their safety, ensuring they get home safe every day. At many of our buildings and stations the greatest safety risk for our passengers and staff is through slips, trips and falls.

During 2016-2017 there were 3,408 (Rail, 2016-17)slips, trips and fall related injuries to passengers on the mainline railway. It is unacceptable to think that across the network there are approximately 10 people per day going home injured due to slips, trips and falls.

fig. 1

fig. 2

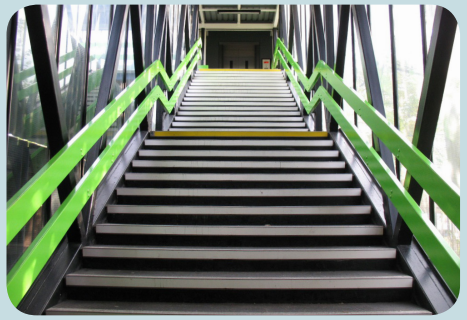


fig. 3

There is significant use of safety signage at stations and various safety messages over the personal address systems advising passengers to be careful at our stations and to use the appropriate method of transportation, i.e. lift, escalator or stairs, depending upon the need of that person.

Despite these methods, however, slips, trips and falls are still prevalent and still remain the highest cause of accident on the infrastructure. The main cause of these incidents is when passengers use the stairs to change levels when accessing the platforms and concourse - if this can be mitigated then it will help to reduce the overall risk of slips, trips and falls.

As stations become busier and serve a larger, ageing population, the need to find more innovative ways to transport customers around our buildings and stations to prevent accidents is increasingly relevant.

Priority problems

Specific priority problems

- Slips, trips and falls pose the greatest risk to passengers at our buildings and stations.
- Changing levels to access the platforms and concourse is the main cause of these accidents.
- High numbers of injuries due to slips, trips and falls on our infrastructure gives Network Rail a poor reputation with regards to passenger safety.

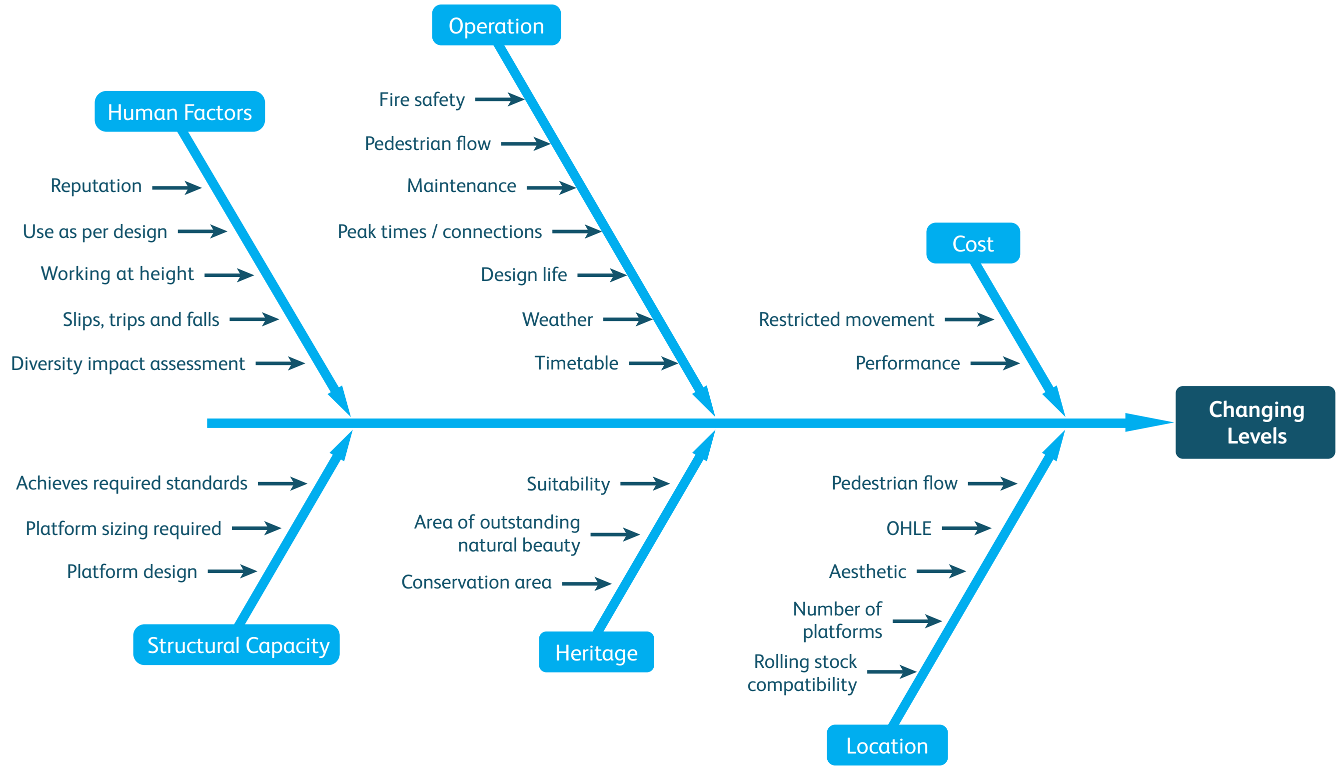
Related goals

- Reduce the amount of accidents, injuries there are on Station infrastructure.

Benefits

- Reduce the number of slips trips and falls in buildings and stations.
- Create a safer mode of transport for moving passengers around building infrastructure.
- Improve passenger flow and use of building infrastructure.

Analysis of causes



Scope

The aim of this project is to develop technology to reduce the need for pedestrians to change levels at Network Rail's buildings and stations.

This means reducing the risk of slips, trips and falls to passengers in Network Rail's buildings and stations, therefore reducing the overall number of accidents on the infrastructure.

The aim is to create an innovative solution that will allow passengers to pass between platforms without the need to change levels, whilst reducing the number of decision points in that process,allowing the passenger to reach their destination.

Specific research needs

To address these challenges it is expected that R&D actions will need to focus on the following aspects:

- Create an innovative solution to reduce the need for passengers to change levels when accessing the platforms and concourse.
- Create a solution to reduce the need for passengers to change levels between boarding a train and the platform interface.
- Reduce the risk of slips trips and falls occurring on Network Rail building infrastructure.
- The focus of this will be on two track railway infrastructure, specifically looking at how to get from platform to platform without changing the level.(There may be more than one solution depending on how the layout can be developed).

Establishing Condition of Hidden Critical Elements

What is the situation?

Exposing hidden critical elements(HCE) during detailed bridge examinations to ascertain their condition.

63,857 Recorded HCEs, which equates to approximately 10,500 examinations per year.

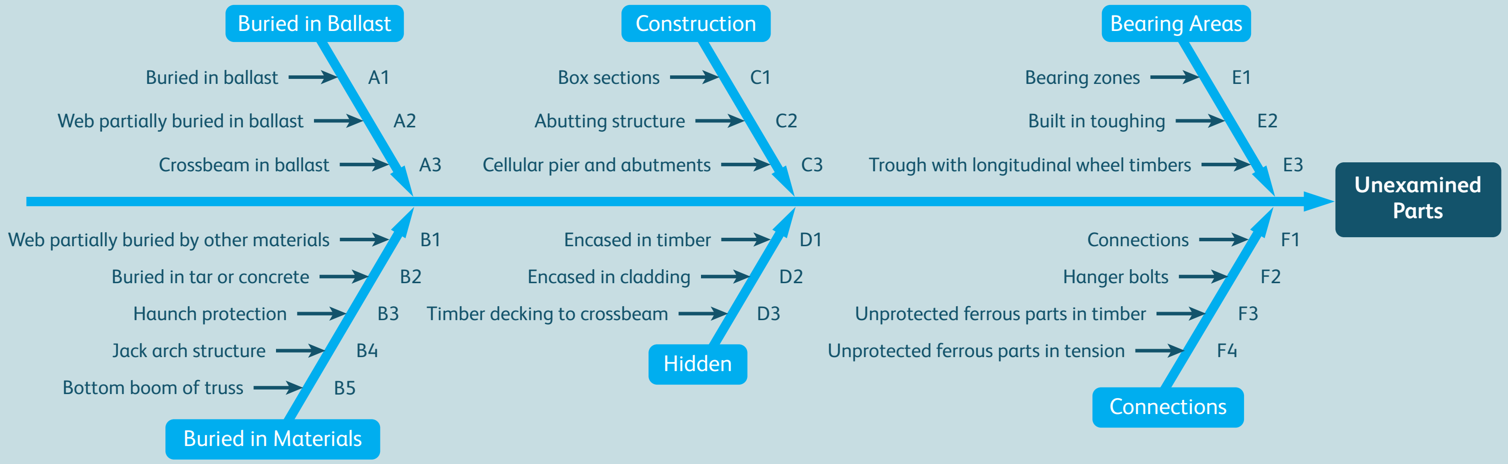
A HCE is a primary structural member that cannot be observed from at least one side throughout its extent and it is not protected by a material which is known to preserve the condition of the part.

The relevance of the unknown condition of hidden parts within structures was brought into focus following the collapse of Stewarton Bridge in 2009. The collapse was linked to the condition of the hidden parts not being sufficiently understood or acted upon. Network Rail has subsequently reviewed its examination processes to specify in more detail the requirements to expose hidden parts of bridges.

63,857 Recorded HCEs,
which equates to approximately 10,500 examinations per year.

Destructive methods are used to expose HCEs - for example, the excavation of ballast to expose buried centre main girders. These destructive methods are expensive, time-consuming, can cause disruption to the network and can disturb protective coatings that were otherwise intact. Deciding the part of the member to expose can raise doubts when ascertaining the 'worse' defected condition.

Analysis of causes



Priority problems

Specific priority problems

- Detection of deterioration. Protection of hidden elements.
- Protection of hidden elements.
- Quicker inspections (reduced possession time).

Benefits

- Examine HCEs without needing enabling works.
- Non-intrusive examination methods.
- Live remote condition monitoring.
- Hidden elements are protected to prevent changes in condition.
- Cheaper, more effective, more durable protective solutions.
- Improved modelling of deterioration of details to enable improved examination and intervention.
- Details and tools to enable quicker exposure of hidden elements.
- Examine HCEs without needing enabling works.

Scope

To address these challenges it is expected that R&D actions will need to address the following aspects:

- Development of technology to enable non-intrusive inspection of metallic structures buried in ballast, concrete or other materials. To confirm the condition of hidden parts, thus omitting the requirement for intrusive investigation, or identifying hidden parts where condition should be confirmed by a limited sample of exposure. This technology would provide the condition of all hidden parts, rather than a small sample.
- Ensure portability of the equipment, and the limited requirement for site calibration, with the technology solution versatile enough to be applied to a diverse structures asset portfolio, including metallic elements with protective (paint) coatings to visible and hidden parts.
- The potential need for software to process the data gathered providing a display/output that can be interpreted by an examiner.
- Development of existing technologies from other industries to enable the inspection of hidden structural elements while providing greater data and information for assessments. Equipment such as magnetic particle testing, ultrasonic testing, electromagnetic testing, and vibration analysis to improve accuracy, operability and miniaturisation of equipment.
- Testing on a representative sample of Network Rail assets under different conditions.
- Research and modelling to help us understand the whole life cost of protective material degradation treatments that aren't being inspected regularly in the railway environment. I.e. the increased access costs with less time to install/maintain but the longer life of assets due to the absence of de-icing salts.
- New design and materials for structures to eliminate the issue of hidden critical elements including research into ballast free bridges.

Expected impact & benefits

The benefits are expected to be:

- A Significant reduction (£m's/annum) in the cost of examination of hidden bridge components, due to intrusive examination not being required.
- Enhanced condition information on which to plan future work banks for maintenance and renewal activities.
- Lower reliance on reactive maintenance to manage safety and performance risk.
- Reduced workforce safety risk associated with undertaking physical works to expose bridge elements.

The costs to Network Rail associated with undertaking intrusive HCE examination can help support the business case for research and development in this area.

Preventing, mitigating and assessing bridge strikes

What is the situation?

Network Rail's budget for management and renewal of structure assets within Control Period 5 (2014-2019) is circa £2bn

Bridge strikes occur whereby a vehicle impacts a bridge that carries the railway or a road over the railway. The challenge is to reduce the number of collisions that take place, ensure that those collisions that still occur do not impact on the railway, and to reduce the level of disruption caused when these incidents arise. After a bridge has been hit, no trains can travel over it until checked to make sure that it's safe. Bridge strikes are always costly and can be fatal for both the driver of the vehicle and the people on or under the bridge.

On average, in afour-weekly period there will be 130 collisions, of which 83 are by a heavy goods vehicle. 9 of these collisions will cause structural damage to the asset; with 2 of them rendering the parapet unsafe. There will be 5 instances of additional service disruption post inspection, with approximately 2.5 speed restrictions put in place.

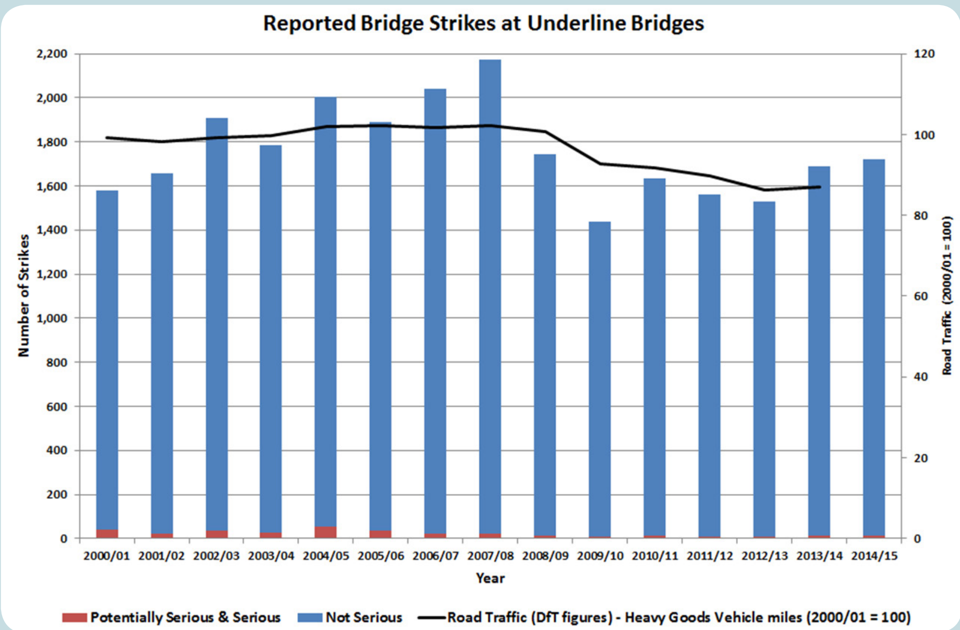
fig. 2

In 2014/15 there were just over 1,800 reported bridge strikes of which 46 strikes were classified as either "Potentially Serious" or "Serious"

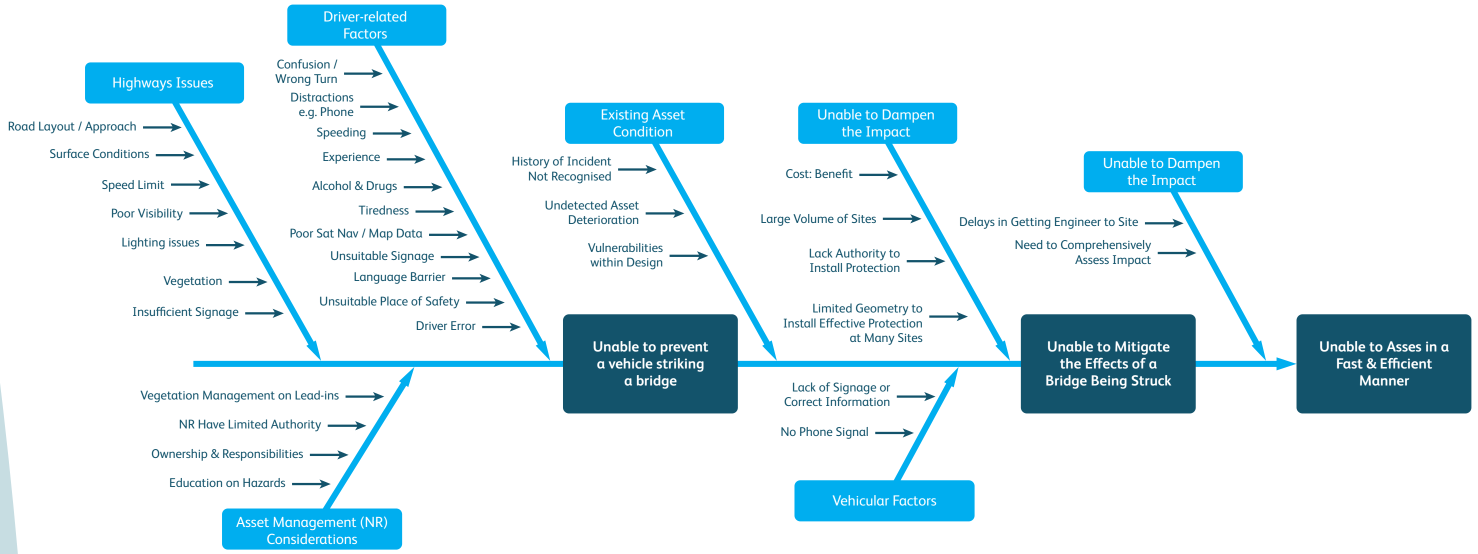
fig. 1

Top 10 bridge strike incidents account for 30,892 delay minutes in CP5 Y2
*Up to end of 2015

fig.3



Analysis of causes



Priority problems

Specific priority problems

- Highway geometry
- Driver related factors
- Unable to reduce impact of bridge strike
- Giving the 'OK' following incident

Related goals

- Reduce number of bridge strikes
- Reduce the effect of bridge strikes upon bridges
- Faster responses and re-opening of lines following incidents

Size of problem

- Reduced delays
- Improved safety
- Less need to repair structures

Scope

To address these challenges it is expected that R&D actions will need to address the following proposals and questions:

- A standard design for free standing bridge protection structures to prevent damage occuring to the bridge and need to stop trains running on the bridge.Consideration should be given to installation costs as well as the requirement for approval from Local Authorities.
- The implementation of a remote condition monitoring solutionto allow the inspection of incidents enabling structures to be given the 'all clear' in a reduced timescale.
- How can we increase the awareness of professional drivers, especially those driving Heavy Goods Vehicles (HGVs), to the dangers of bridge strikes?

Scour prevention and management

What is the Situation?

Scour is the removal of material from the bed and banks of a channel and from around structure foundations by the action of water, leading to structural damage or failure. Scour is the leading cause of bridge failures in the last 100 years in the UK.

Diver inspections are currently used to detect scour. The outcome is often uncertain due to low water visibility, resulting in ambiguities and inherent risk at structures.

During flood events, bridges at risk of scour may have restrictions placed upon them (including closure) as a safety precaution. The restrictions can only be lifted following an inspection by divers or through flood waters receding, once an engineer has satisfied him or herself that no scour/erosion/damage has occurred that could affect the structural integrity.

CP5 National Costs for protective works is £27m

Estimated Likely Failure of Bridge due to Scour 27% of failure or 1 in every 3.7 years*

**from JBA Trust (2013) 'Flood and related Failure incidents at Railway Assets between 1846 & 2013' report*

47 years during which one or more structural failures were observed in the UK

RSSB T112 Report (2004) 60 failures over approx. 150 years.

No downward trend or risk reduction noted.

4500 structures at risk of scour
750 rated as High or Medium/High risk

Analysis of Causes

The factors causing scour to develop are complex and differ according to the type of structure. Scour solutions can be summarised into 3 areas:

Identify:

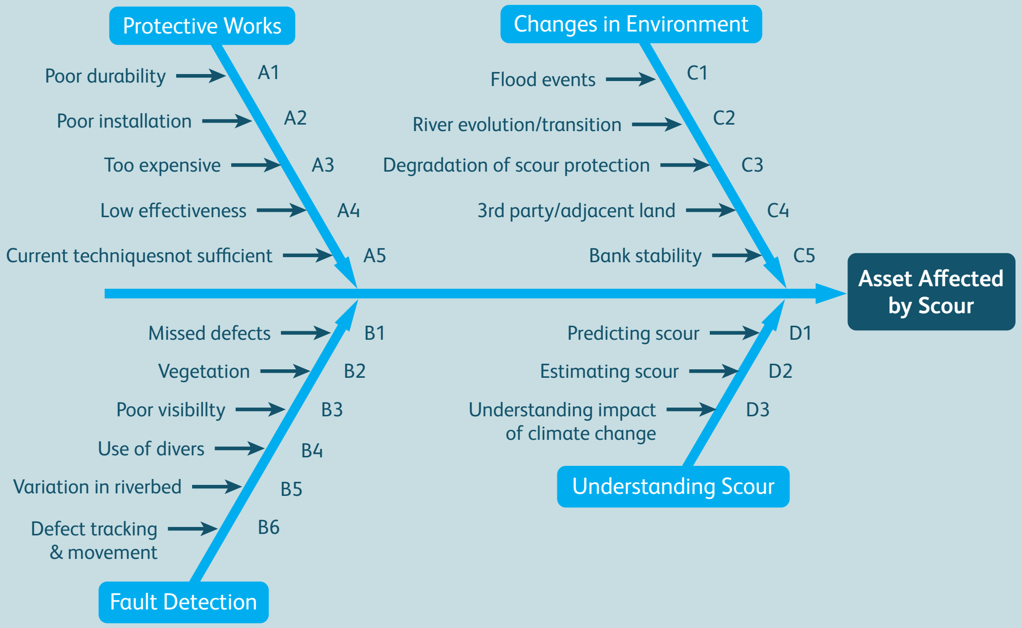
Development of tools to accurately predict level of scour at structures

Protect:

Physical works to alter scour susceptible structures to protect them during high flow events

Detect:

During flood conditions confirm scour conditions and monitor.



Priority Problems

Specific Priority Problems

- Detection of scour
- Improved safety of workforce
- Protective physical works
- Prediction of scour

Related Goals

- Overcoming poor visibility
- Live remote condition monitoring
- Reduced need for divers in examinations and assessments
- Cheaper, more effective, more durable protective solutions
- Better understanding scour processes and failure mechanisms

Benefits

- Safer workforce.
- The risk profile of assets reduced.
- Reduction in time that asset is closed during extreme weather events.

Scope

To address these challenges it is expected that R&D actions will need to address the following aspects:

The use of technology to determine if/when infrastructure can be re-opened following a flood event.

Divers are generally used to inspect river beds and check structural integrity below the water line. In many cases, this leads to delays re-opening the structure as water conditions can prevent divers being able to gain access to the water. Some form of remote monitoring would also result in much safer working practices.

Notes:

- The System would need to provide positive confirmation that bed levels have not dropped and/or supports remain intact.
- Scour holes generated by floods tend to re-fill at lower flow rates, but may not attain the original support characteristics.
- Some scour could be acceptable at certain structures (can the system detect this?)
- Costs need to be proportionate, ultimately remedial works (such as solid inverts/rock armour) can greatly reduce scour risk.

Establishment of foundation type/depth

Foundation depth is one of the most critical factors for understanding scour risk at a structure. Foundation depths are currently investigated by core drilling, which is intrusive, expensive and sometimes not particularly accurate.

A non-intrusive technology that could accurately determine an asset's foundation depths, type and condition would be a huge benefit.

Alternative cost-effective, easy to install, robust scour protection techniques

(Acceptable to Environment Agency/NRW/SEPA)

Established current scour protection techniques are in many cases not proving resilient due to the use of concrete in watercourses which is problematic environmentally.

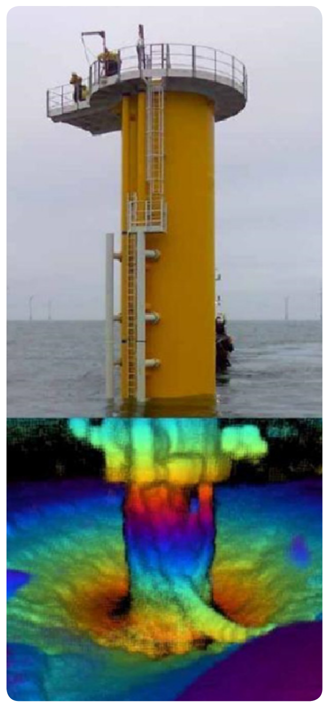


fig. 1 Offshore wind turbine from Echo scope

fig. 2 - ARC boat

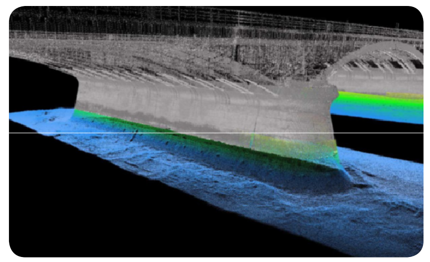


fig. 3 - Comtreer model using multiple data sources

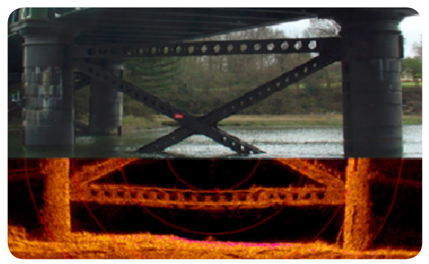


fig. 4 - MS 1171 High-resolution vertical imaging

fig. 5 - Submersible remote camera

Tenanted Arches

What is the situation?

Access problems combined with the difficulty of examining elevated railway structure elements, mean that many of the inherent risks of tenanted arches across the rail network are unknown and unquantified.

Inspection access to tenanted arches is often limited as past contracts didn't include access requirements. The arches are often lined to provide adequate conditions tenants, but the lining conceals the structural elements and any possible defects. Consequently, the lining needs to be temporarily removed for examination.

10,425 tenanted arches in structures portfolio

Assessment tools developed in 1970's calculate capacity based on Ultimate Limit State (ULS), whereas modern thinking believes Service Limit State (SLS) could be more relevant to the management and service life of masonry arches.

fig. 1

fig. 2

Analysis of causes

Threat	Barriers to failure								Event
Material Degradation	Design & Construction	Manage Adhoc reports	Analyse traffic changes	Control NR infrastructure activities	Carry out examinations	Structural assessment	Routine maintenance	Demolish or remove from service	Functional asset failure
Defects develop in elements over time	Asset not originally designed for cladding	Reliant on tennant		Lack of control over all activi-ties at asset	Unable to veiw all of asset	Unsuitable assessment tools	Unable to access all of asset		Asset is not safe to use

Priority problems

Specific priority problems

- Assets not originally design for cladding.
- Unable to view all of asset .
- Unable to access structure.
- Size of issue not truly understood.
- Tenant safety.
- Understanding of masonry arch capability.
- Moisture / damp degrading masonry / mortar.

Related goals

- Remote monitoring.
- Reduced number of defects by slowing or preventing material degradation.
- Inspection with-out removing cladding.
- Protection of tenant.
- Improved understanding of masonry arch behaviour.

Benefits

- Don't need to access arches for inspections.
- Reduced need for maintenance.
- Improved neighbour relations.
- Improved safety of tenants.
- Safer running of trains.

Scope

To address these challenges it is expected that R&D actions will need to address the following aspects:

- Remote condition monitoring: Any technology installed during an arch refurbishment will need to identify defects with the same accuracy as the intrusive, cladding-removal method that we use today.
- Technology that can restore or improve the condition and capability of an arch. This solution should be cost-effective, compared with an intrusive examination, but also deliver a high degree of confidence that its use will reduce the volume and number of defects to measurable levels.
- Hidden inspection techniques: A solution that can detect defects in masonry without the need to remove cladding. Any technology identified or developed must identify defects with the same accuracy as current methods, where cladding has been removed.
- Improved detection of defects, and a better understanding of the deterioration and impact of masonry defects. Identify or develop a technology that detects masonry defects earlier in their development. To do this we need a better understanding of how masonry deteriorates and also knowledge of the turning-point at which the level of risk from the defect is no longer acceptable.
- The development of a standard design to Line systems that form a protective barrier. This design solution must take account other T&I developments as any protective barrier solution will also block access to perform maintenance and repairs to the arch face.
- Development of an improved masonry arch assessment tool to understand the impact of defects and condition on asset capability.

Expected impact & benefits

Primary Benefit

- Reduction in the risk profile of tenanted masonry arch structures to both the occupying tenants and the railway.

SecondaryBenefits

- Improved tenant relationships.
- Reduction in examination cost.
- Reduction in examination non-compliance on tenanted arches.
- Improved asset management of masonry arches, possibly including increased capability.
- Development of improved examination process for use on all masonry assets.

Provide a Safe and Efficient Method to Enable Building Facade Inspections Without Impacting on the Operation of the Environs (including inaccessible, hard to reach or hidden elements)

What is the situation?

Our headline Business Critical Rules are 'Loss of safe environment' and 'Objects Falling from height leading to injury'. These incidents occur at a variety of locations including railway stations, lineside buildings, depots, car parks and other property assets.

Visual inspections are currently ground based, using binoculars and not sufficiently robust.

The inspection quality problems are:

- Some parts are hidden (in particular, wall tiles).
- A lack of tactile inspection.
- Poor visibility and generally a lack of detail.
- The defect can only be seen from one angle.
- Limited ways to give a condition marking index based on quantitative measures.
- Subject to weather conditions and the ability of the inspector.

The problems with access solutions are:

- Accessing station buildings is problematic and very few man safe systems are available.
- Some areas are hard to reach even with abseiling
- Working at height should be minimised as it is a safety risk.

A inspection notice was issued in 2015 to try and understand the scale of the problem, which highlighted the difficulty in undertaking these kinds of inspections.

fig. 1

fig. 2

fig. 3

Priority problems

Specific priority problems

- Safe methodology to obtain the condition data of building facades to reduce safety risks for the workforce and the public.
- To enable short, medium and long-term asset management decisions through accurate data-analysis and intelligence.
- Improved competency for heritage specialisms.

Related goals

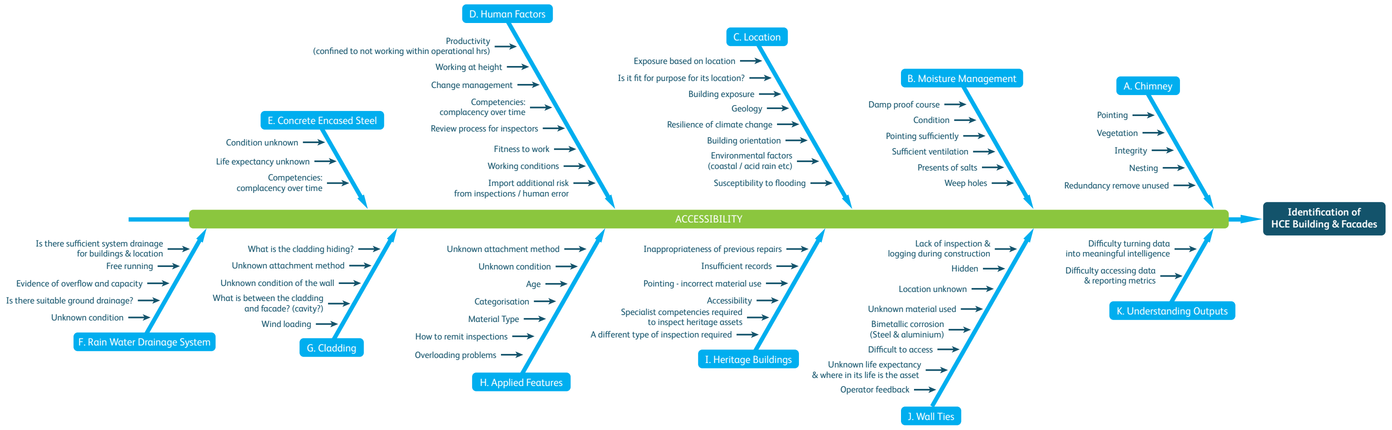
- To inspect 50 % of assets with automated technology by CP8.
- To be able to access all assets so as to collect the service and structural condition, whether physically or remotely, by CP7.
- To fully discharge our Heritage obligations by CP6.

Benefits

- Safe and efficient inspections and monitoring activities will help complete the asset inventory and capture the asset status.
- Timely and effective inspections will help reduce the number of failures, improving the safety of the network.
- Reduced risk of a Heritage fine.

NetworkRail

Analysis of causes



Specific research needs

To address these challenges it is expected that R&D actions will need to address the following aspects:

Lack of safe methodologies to inspect

How can we inspect inaccessible building facades? How do we get the facade to the expert instead of the expert to the facade? How can we inspect and make it safe simultaneously? How do we do this when the station is operational?

Remote condition monitoring and early warning detection of asset failure are required especially for hidden critical elements. How can we identify abnormal indicators or precursors of failure.

What do other asset owners do to monitor their assets? Can we adopt any effective methods or techniques from other industries?

What are the common failure modes for particular material types? What are the risks for these failure modes?
Are there remote (hands-off proxy) methods for collecting quantitative and consistent data that reduces subjectivity?
Is there something already available in other industries that we can implement?

Insufficient decision support tools

How can top-down, whole-life cost modelling be achieved? What new models need to be developed and combined with existing models to account for factors such as degradation, capability analysis, climate change, weather resilience etc.? How do we implement an asset risk register relating to extreme weather, based on location, asset condition and criticality?

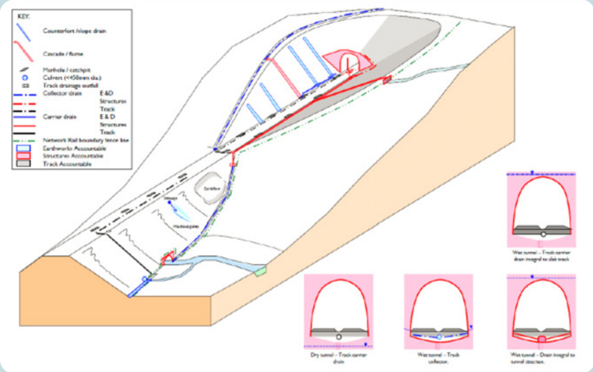
How can the findings be easily and clearly communicated to building surveyors and asset engineers and give time-framed action recommendations?
How can current and new processes be managed better with decision support tools? What is required to develop a live bottom-up work-bank tool and how would this integrate with existing systems? How can intervention scenarios be modelled in order to support business planning?

Output vision

An inspection methodology that enables quantitative data to be collected so that the condition of hidden or inaccessible elements and hard to reach areas can be more fully understood. This needs to be undertaken in keeping with our safety requirements and whole life cost principles. In maximum safety but with minimum cost and disruption. The output should enable surveyors and asset engineers to clearly understand the condition, enabling them to make time-framed decisions.

Efficient and Effective Drainage Interventions

What is the situation?

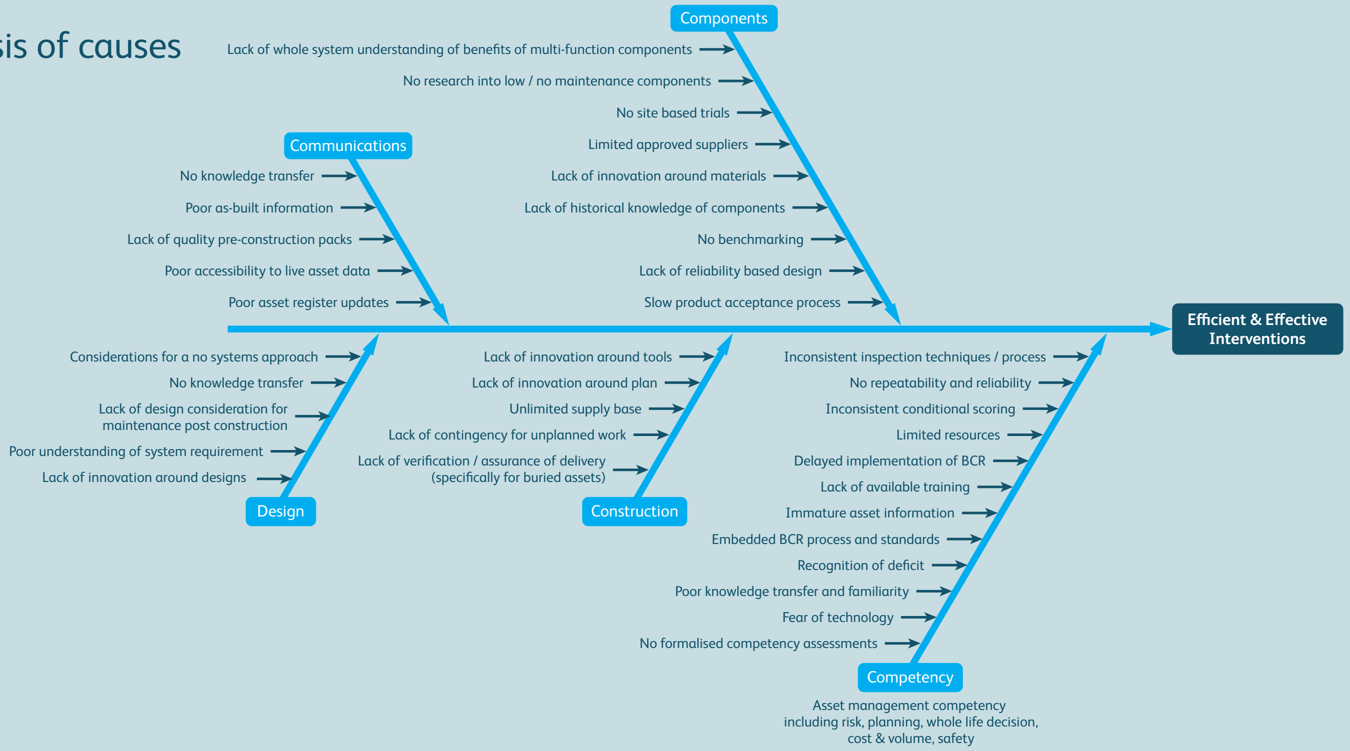


The effective control of water is essential to the safe and economic management of railway infrastructure.

Drainage has an important role in reducing the degradation mechanisms caused by water; such as the long-term softening of materials that form the track support system and earthworks.

Neglect of the drainage system can have significant cost and safety implications for the parent asset; such as delay minutes, poor track geometry, line closures and a likelihood of earthwork failures.

Analysis of causes



Priority problems

Specific priority problems

- Lack of innovation around construction tools and methods.
- Lack of innovation with regards to use of low maintenance materials.
- Poor communication channels and update of asset inventory.

Related goals

- To benchmark against other sectors and trial innovative construction tools and methods by CP7.
- To benchmark and trial low maintenance construction materials that could replace traditional materials by CP7.
- To provide all those delivering drainage works with training and access to the My Works App for drainage as well as guidance on how to capture work and volumes delivered by CP7.

Benefits

- The use of innovation in construction methods, tools and materials will help to provide more efficient interventions.
- This will also provide workforce safety benefits, and reliability and repeatability in the works completed.

Scope

Management of the drainage system requires effective and efficient interventions throughout the whole life cycle. Timely interventions can reduce the risk of drainage and parent asset failure, providing significant cost and safety benefits.

Interventions can range in size and scope from dealing with the maintenance of one chamber to the refurbishment of a whole crest drain. However, they should be approached with a holistic view with its suitability and value measured by the performance of the whole system. Currently, the majority of interventions are delivered by traditional methods with a lack of innovation and technological advancement. There is a need to consider where technology and more novel solutions/materials could be employed throughout the construction process.

The enablers to supporting efficient and effective interventions are:

- Components.
- Design.
- Construction.
- Competency.
- Communication.

fig. 1

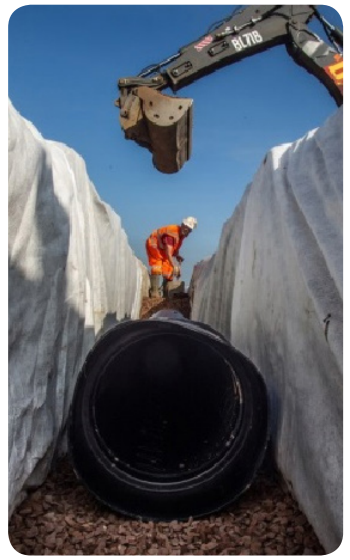


fig. 2

Providing a solution to the issues highlighted for each individual enabler (see Analysis of Causes) will allow for efficient and effective interventions.

To address these challenges it is expected that R&D actions will need to address the following aspects:

Innovation around construction tools & methods

- How can current construction methods, equipment, plant and tools be made more efficient and effective with the use of technology and innovative solutions?
- Improving construction quality and reducing construction time are desirable for all clients.
- Improvements around excavations and trenches will also increase safety by reducing risk.

Innovation with regards to use of low maintenance materials

- What low maintenance drainage materials, components and solutions exist?
- How can existing high maintenance drainage components be replaced by low or no-maintenance components with minimal disruption to the railway?
- Increasing rail capacity means that access to the railway is reduced for maintenance works.

fig. 3

Improved communication channels

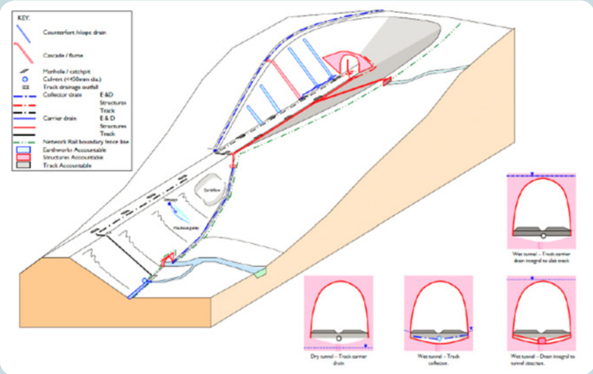
- What tools are required to support the information flow between asset managers and deliverers? Timely transmission of data during the various phases of design and construction can reduce the costs of projects.

State of the art drainage designs

- How can drainage designs deliver low or no maintenance solutions with resilience?
- Best practice and world class drainage designs supported by innovative components can provide safety and performance benefits not yet realised.

Improving Drainage Asset Management Decision Making

What is the situation?



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Analysis of causes

Priority problems

Specific priority problems

- Lack of models including a top-down whole life modelling tool.
- Insufficient decision support tools.
- Insufficient tools and datasets to manage, view, map drainage as a system including a workflow management system.

Related goals

- To produce a top-down whole life cycle and cost model for drainage by CP7.
- To produce a bottom-up decision support work-bank tool by CP6.
- Drainage systems identified, connected, linked to system and mapped by CP6.
- Models to support planning via intervention scenarios at the system level.

Benefits

- This will enable more efficient and effective decision making that will provide both cost and safety benefits.
- Asset management underpins the whole life cycle of an asset base. Fit for purpose decision support tools, models and datasets will allow for informed decisions to be made that will improve life extension, safety, performance, resilience.

NetworkRail

Scope

The ability to make timely and effective decisions is a key factor in managing the assets in accordance with policy and strategy. Better decision making can help target drainage interventions and manage the system at an optimum whole life cost. Efficient, accurate and traceable decision making can also provide significant safety benefits by improving the condition of the parent assets and reducing the likelihood of failure.

fig. 1

The enablers to supporting better decision making are:

- Data Management.
- Decision Support Tools.
- Modelling.
- Systems Approach.
- Competency.

Providing a solution to the issues highlighted for each individual enabler (see below) will allow for safer, more reliable and efficient drainage systems.

fig. 2

Specific research needs

To address these challenges it is expected that R&D actions will need to address the following aspects:

1. **Models and top-down whole life modelling tool**

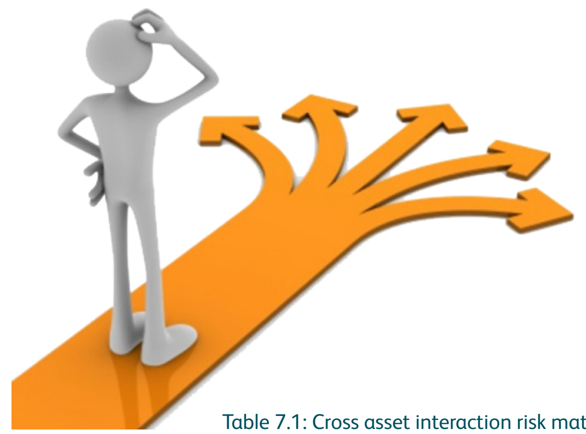
   How can top-down whole life cost modelling of drainage be achieved? What new models need to be developed and combined with existing models to account for factors such as degradation, capability analysis, flood risks due to land use change, climate change, weather resilience etc.?

2. **Decision support tools**

   How can current and new processes be managed better with decision support tools? What is required to develop a live bottom-up work-bank tool and how would this integrate with existing systems? How can intervention scenarios be modelled at a system level in order to support business planning?

3. **Tools and datasets to manage, view, map drainage as a system**

   How can we map and view drainage as a system? Tools and datasets are required for the management of drainage from a holistic systems approach. The developed tools should support the decision-making process and allow for timely interventions providing both whole life cost and safety benefits.



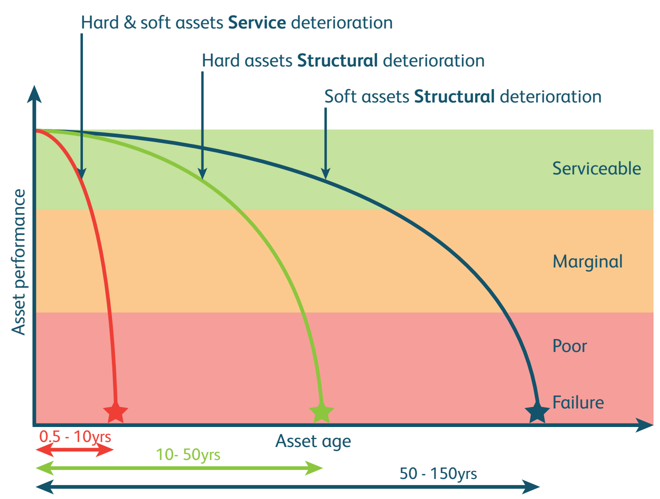
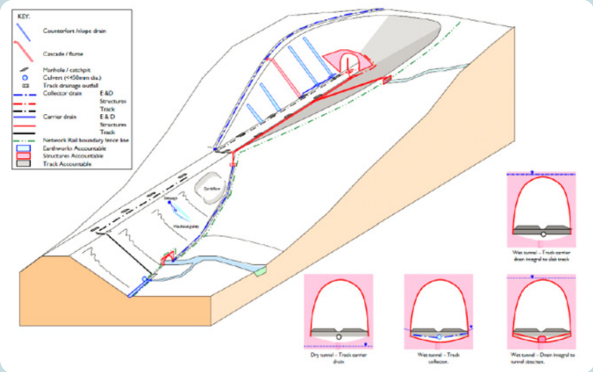


Table 7.1: Cross asset interaction risk matrix

Drainage performance	Track, earthworks or asset condition (related to drainage)		
	Serviceable	Marginal	Poor
Serviceable	Lowest risk	Slight risk	High Risk
Marginal	Slight risk	Moderate risk	High Risk
Poor (including under capacity)	Moderate risk	High Risk	Highest risk
Serviceable	Slight risk	Moderate risk	Highest risk

Improving Drainage System Performance

What is the situation?



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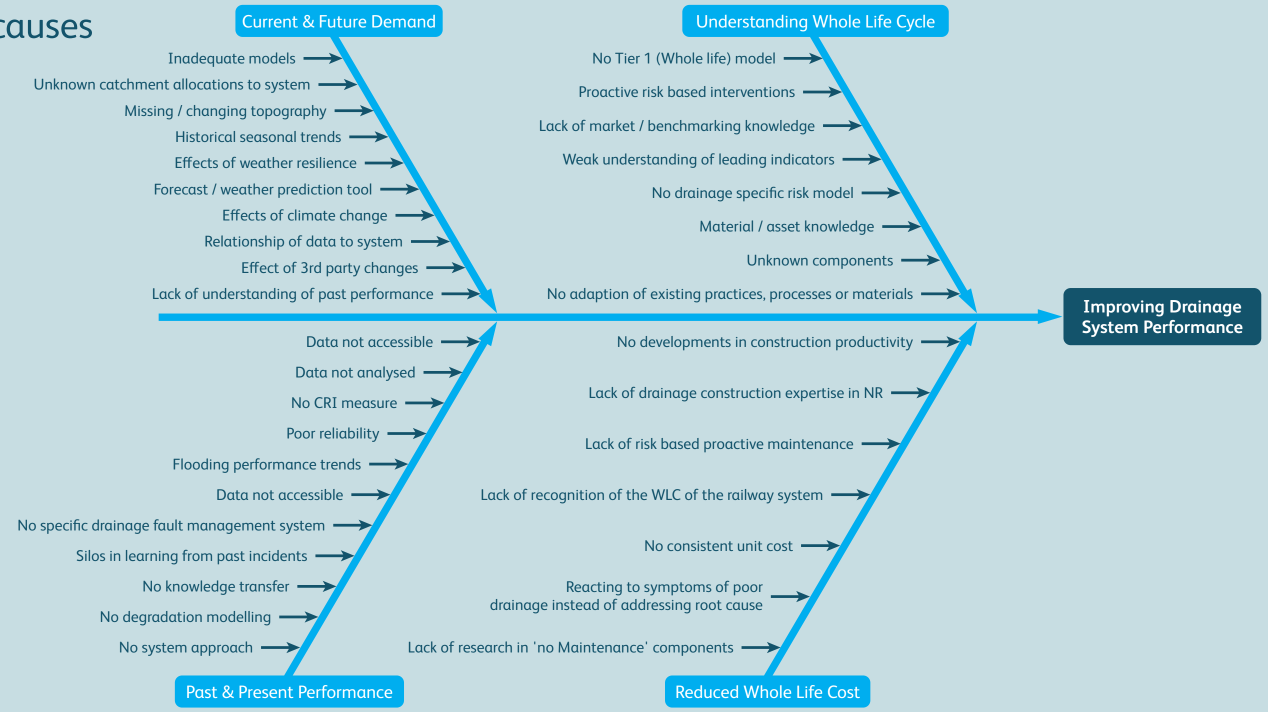
Analysis of causes



Priority problems

Specific priority problems

- Now-casting and fore-casting demand on drainage system.
- Understanding whole life cost of drainage system.
- Understanding whole life cycle of drainage system – concept to demolition.
- Measuring system performance - including impact on parent asset and social/environmental/reputation factors.

Related goals

- To measure and monitor performance of system by CP6.
- Understanding whole life cost and cycle to support modelling, prioritisation and business planning for CP7.
- Demand analysis in order to support business planning, risk identification and long-term investment strategies.

Benefits

- Improvements to drainage system performance are facilitated through an understanding of demand, whole life and investment strategy.
- Setting key parameters to monitor which equate to performance allows for continual improvement through targeted and measurable activities.
- Improving performance will naturally lead to improving safety and resilience.

NetworkRail

Scope

Improving drainage system performance doesn't simply focus on effective maintenance or intervention techniques, but considers a holistic view of the effects of the system. A plan-do-review cycle is required to support continual improvement. The review phase of the cycle is via measuring and monitoring performance. At a basic level, the enablers which support a better understanding of performance and allow for improvements are:

- Current and Future Demand (now-casting and forecasting).
- Understanding Whole Life Cycle.
- Reducing Whole Life Cost.
- Past and Present Performance.

Providing a solution to the issues highlighted will allow for improvements to the drainage system performance by providing the 'review' phase of the plan-do-review cycle, supporting NR's commitment to continuous improvement.

To address these challenges it is expected that R&D actions will need to address the following aspects:

Qualitative & quantitative demand analysis tools

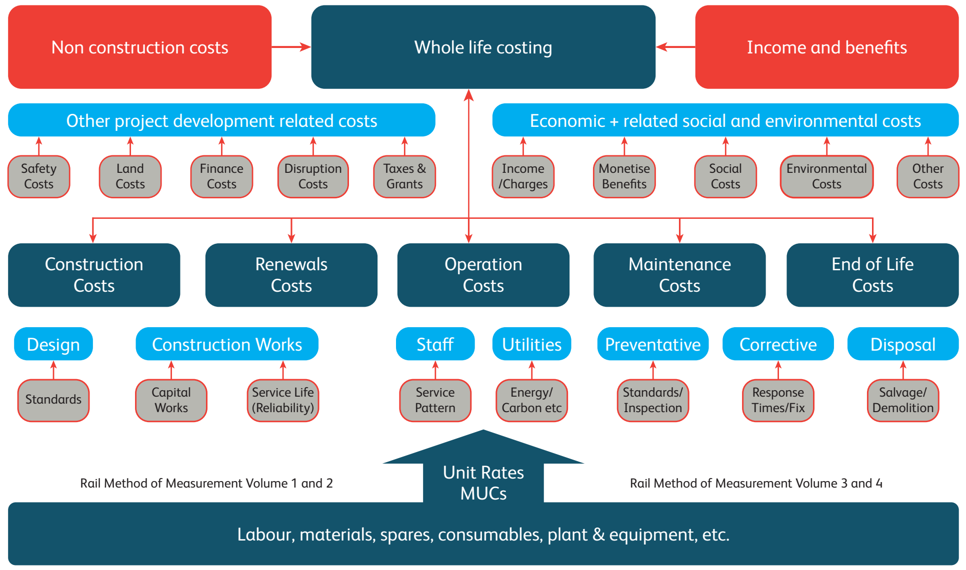
- (now-casting) How can current demand on a drainage system be captured and quantified?
- (forecasting) How can future demand, based on extreme/adverse weather and climate change be improved to provide enough time for a response?
- Demand analysis is vital in determining the capability of the drainage system as well as contingency planning.

Drainage system whole life models

- How can the drainage system's whole life cycle, including costs, be modelled?
- Whole life modelling supports better decision making as well as improvements to performance.
- Continual improvement to business processes and standards would be underpinned by a greater understanding of whole life cycle.

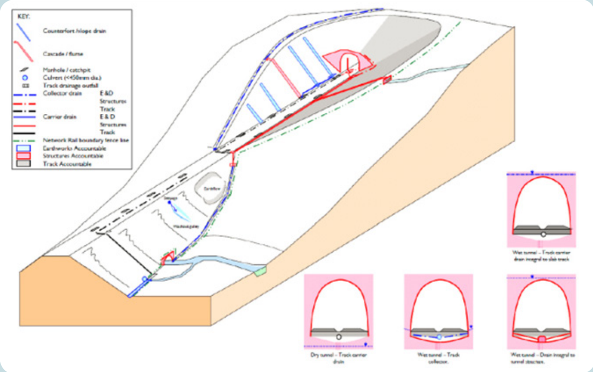
Holistic system performance measure

- How can the drainage system be measured so that the performance covers not only operations disruptions, but also social, reputation, environmental impact?
- How can measures be monitored at the correct frequency and with quality data in order to be responsive and trusted?
- Performance measures allow for a business to review asset management and interventions and provide confidence that best practice/continual improvement practices are in place.



Safe and Efficient Drainage Inspections and Monitoring

What is the situation?



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Analysis of causes

Priority problems

Specific priority problems

- Limitations of Technology – hardware, software and middleware.
- Locating and accessing assets.
- Insufficient tools and datasets to manage, view, map drainage as a system.

Related goals

- To inspect 50 % of assets with automated technology by CP8.
- To be able to access all assets so as to collect the service and structural condition; whether physically or remotely by CP7.
- Drainage systems identified, connected, linked to system and mapped by CP6.

Benefits

- Safe and efficient inspections/ monitoring activities will help to complete the asset inventory and capture the status of the asset.
- Timely and effective inspections will help reduce the number of failures, improving the safety of the network.
- The use of automated technology will provide workforce safety benefits, reliability and repeatability and data required to make correct decisions.

Scope

The effective management of the drainage system requires a complete, well maintained and up-to-date asset inventory. This is achieved by regularly inspecting the assets to capture the core attributes required to effectively manage the drainage systems.

The data captured by routine inspections and monitoring is used in decision making tools and processes to help manage the asset base in the most cost effective and safe manner. Inspections also identify the condition of the drainage assets such that degradation, priority and risk. The impact of the current drainage condition on the parent assets is vital in managing safety and performance.

The enablers to supporting safe and efficient inspections and monitoring are:

- Location.
- Technology.
- Dedicated resources.
- Competency.
- Systems approach.

fig. 1

fig. 2

Providing a solution to the issues highlighted allows for safer and more efficient inspections/monitoring. Providing a more complete dataset from which to manage drainage and its parent assets from a systems approach.

To address these challenges it is expected that R&D actions will need to address the following aspects:

Automated technology e.g. train borne, robotics, drones etc.

- How can automated technology be used to inspect and monitor drainage assets? In particular what train-borne devices can be used to regularly inspect and monitor assets? Considerations should also be made for how such technology would integrate with existing systems and the management of the data.

Manual technology e.g. handheld, desk based tools etc.

- What manual technology such as handheld inspection desk based tools can be used to improve the efficiency of drainage inspections?
- Can similar tools be used to remotely monitor and inspect assets in high-risk locations or where significant safety and efficiency gains can be achieved?

Locating & accessing assets

- How can buried assets or those that are hard to access be routinely inspected or monitored in a safe, efficient, reliable and consistent manner?

Tools and datasets to manage, view, map drainage as a system

- How can we map and view drainage as a system? Tools and datasets are required for the management of drainage from a holistic systems approach. The developed tools should support the decision making process and allow for timely interventions providing both whole life cost and safety benefits.

Percentage of total assets with structural score

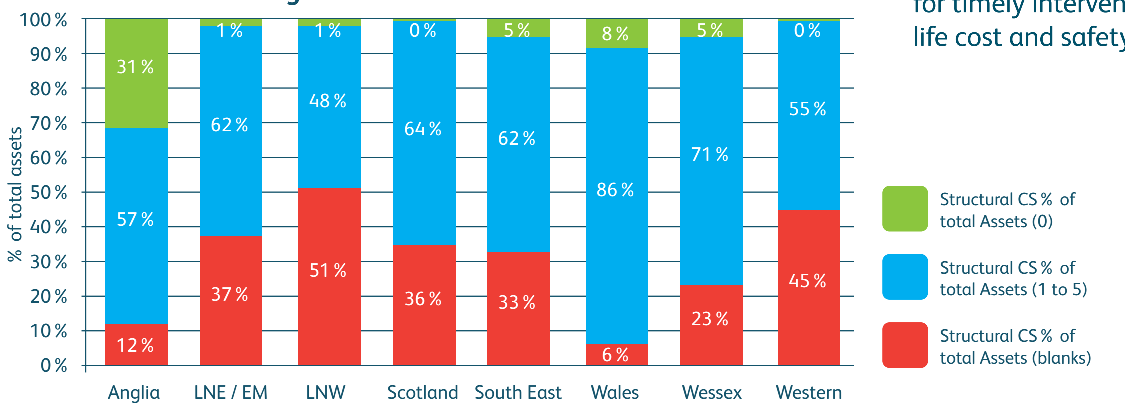
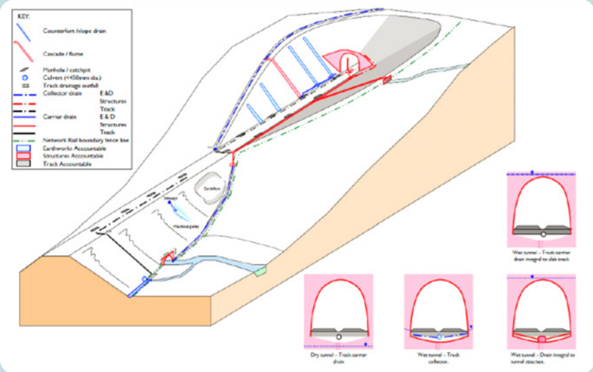


fig. 3

Understanding Drainage System Capability

What is the situation?



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Analysis of causes

Priority problems

Problems

- Incomplete and immature asset inventory.
- Capturing condition and location information.
- Insufficient tools and datasets to manage, view and map drainage as a system.
- Unable to measure the capacity of a drainage system.
- Insufficient datasets and models to calculate the past, present and future demands on the system.

Related goals

- To complete the asset inventory so that 95 % of assets are within Ellipse by CP7.
- All assets should have condition and GIS location information by CP7.
- Drainage systems identified and mapped on Geo-RINM or equivalent platform.
- Capacity of individual systems recorded in asset register.
- Complete demand analysis of each system.

Benefits

- Enabling proactive drainage management, to target maintenance and intervention activities at the most high-risk locations and in a timely cost-effective manner.

NetworkRail

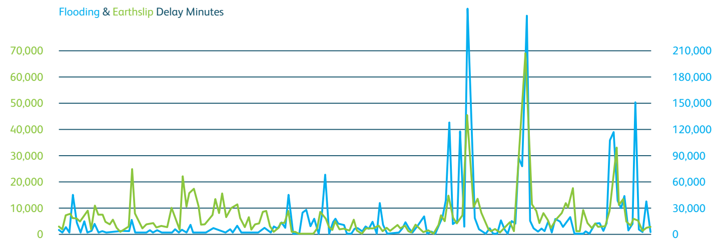
Scope

The effective management of a drainage system requires a complete understanding of its capability. This is based upon a holistic approach in which drainage is viewed and managed as a system from the infall to outfall, rather than as individual components.

A full understanding of the system capability is dependent on the knowledge of:

- A complete and accurate asset inventory.
- Location, condition, and performance data.
- A measure of the capacity of the system.
- Current and future demand.
- Competency.
- Systems approach.

A better understanding of these key components, alongside the enablers to capture the necessary data will allow for the drainage system capability to be measured.



To address these challenges it is expected that R&D actions will need to address the following aspects:

Incomplete & immature asset inventory

- What tools and processes are required to achieve a complete asset inventory?
- How can the data with the asset inventory be maintained and managed in the most effective manner?
- Considerations should be made on the accessibility of the data and systems required to manage the workflow.

Capturing condition & tocation information

- What tools and processes are available to capture asset data efficiently and safely?
- Considerations should be given as to how these tools/processes will integrate with current systems e.g. Ellipse.

Measurement of the capacity of a drainage system

- What tools and processes are needed to measure the capacity of a drainage system?
- How can we locate and measure the capacity of difficult to access or buried assets?

Data sets & models to calculate the past, present & future demand on the system.

- What datasets and tools are available or need to be developed to calculate the past, present and future demand on a drainage system?
- How can these datasets be integrated with existing processes and systems, supporting the management of drainage assets decision making progress?

Tools & datasets to manage, view, map drainage as a system

- How can we map and view drainage as a system?
- Tools and datasets are required for the management of drainage from a holistic systems approach. The developed tools should support the decision-making process and allow for scheduled interventions. Providing cost and safety benefits over the whole life of the system.

Detection of Geotechnical Asset Failure by Means Other than Train Drivers or Lineside Staff

What is the situation?

Network Rail manage over 190,000 earthwork 5 chain assets on a cyclical inspection regime.

Geotechnical assets have a high passenger risk due to the high chance that a failed asset will derail a train when struck.

Geotechnical failures are frequently reported by train drivers reported as obscuredbank slips or rough rides. This is too late for preventative measures to be put in place.

Geotechnical failures are often first reported by train drivers, for example through rough rides on embankments. This is too late for preventative measures to be put in place. These observations are not currently integrated into earthwork examinations and analysis.

Condition inspections of geotechnical assets rely heavily on data collected by examiners in the field. Many of the data sets collected are subjective creating incomparable, and sometimes unreliable, data sets. This limits the extent to which asset condition and potential failure can be accurately determined.

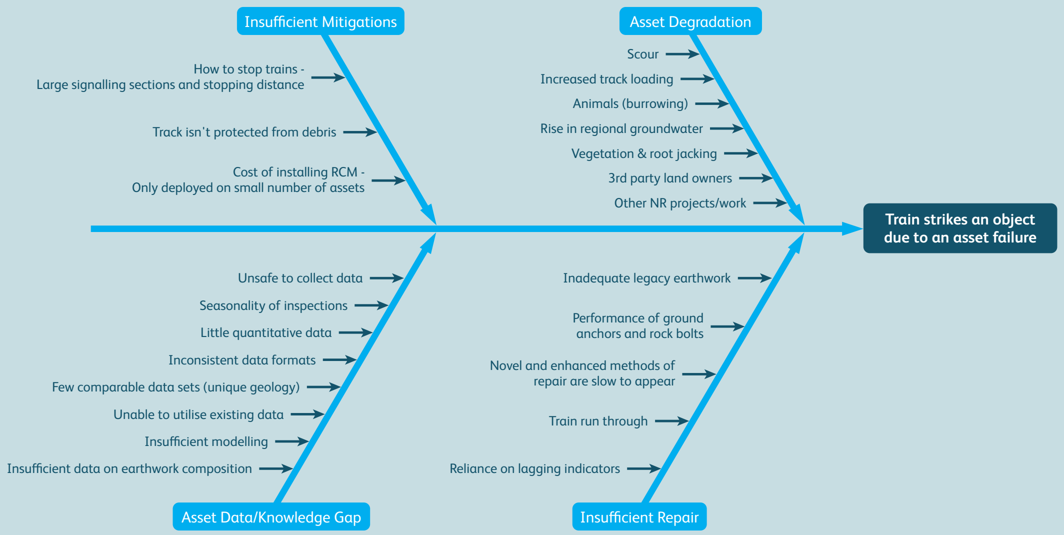
Most data capture requires an examiner to go on site. This is time-consuming and limits the frequency that condition data can be collected. Access to inspect assets is often difficult, especially when accessing through third party land. Some third party assets also pose a risk to the railway e.g. slopes outside our boundary and boulders.

The composition and soil parameters of embankments are poorly known making it hard to assess stability.

Data is collected across the network for specific projects (e.g. GI studies) but the data sets are not stored and collated centrally which leads to a lack of understanding of the geotechnical asset as a whole.

Full LiDAR survey of the network has been undertaken and base geometry data has been produced.

Analysis of causes



Priority problems

Specific priority problems

- Lack of quantitative data sets from Earthwork examiners.
- Unknown parameters and soil characteristics across the asset base affect the ease that 'off-the-shelf' solutions can be used.
- Processing and interpreting track data holistically across all embankments for geotechnical asset management.
- Access to third party land.

Related goals

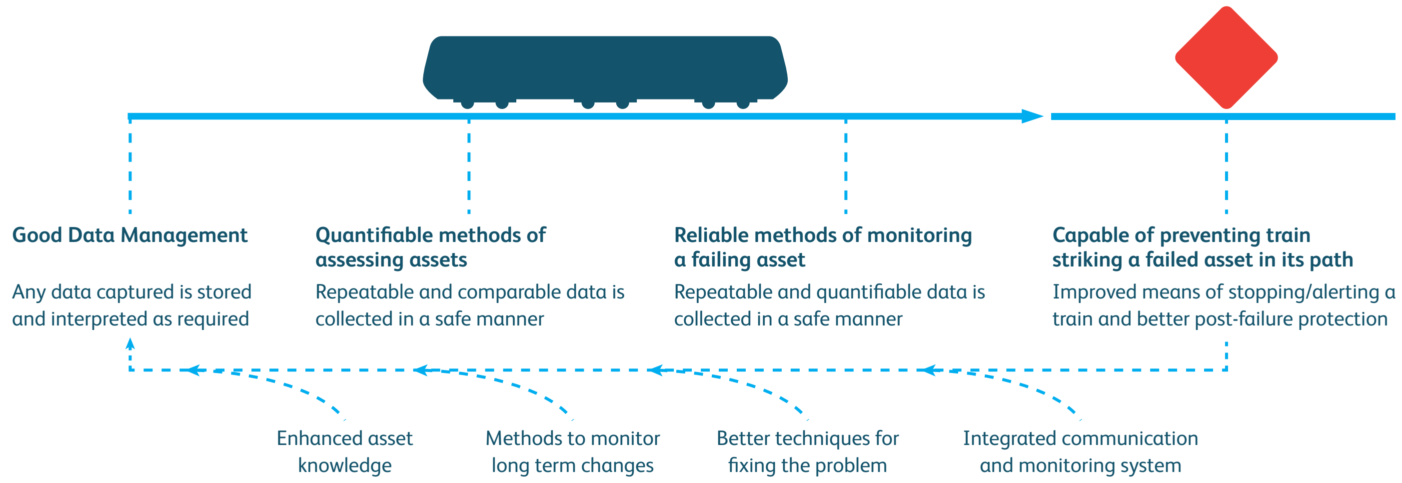
- To have access to more quantitative data sets on earthwork condition.
- Greater understanding of the asset base to feed into geotechnical assessments.
- Improved use of existing gathered data from other disciplines.
- Be capable of assessing the risks of third party land without needing to access non-NR property.

Scope

The scope of the challenge is to explore how quantitative data sets can be collected and combined so prioritised intervention can take place before failure.

The scope covers the development of novel techniques to monitor and assess earthworks at portfolio level. In addition data sets from other asset groups (e.g. track) currently collected require collation and integration to gain a better understanding of the geotechnical asset.

Consistency and repeatability of data outputs are key to ensure analysis can be carried out to detect change and prioritise intervention.



Specific research needs

To address these challenges it is expected that R&D actions will need to address the following aspects:

- Using data sets from across different disciplines (e.g. Plain line pattern recognition, track recording vehicle) to analyse cross-level features on embankments. Crucially, analysis must link to earthwork 5 chain lengths.
- Carry out more frequent LiDAR flights to enable comparison of data. Proof of concept required to visualise changes, automated flagging of changes (e.g. toe bulges) and efficient data management and visualisation of large data sets.
- Novel techniques and cost effective technologies to consistently acquire and store ground investigation (GI) data to better understand soil characteristics across the asset base.
- Techniques to assess and monitor geotechnical assets outside our boundary.

Expected impact & benefits

- Better knowledge of asset with quantitative data across the whole geotechnical asset portfolio
- More informed decision making and prioritisation of intervention through use of consistent data
- Greater intervention before failure and therefore reduced risk of derailment
- Reduction in Schedule 8 costs by fixing before disruption and failure

Implementing Energy Reduction Activities to Reduce our Carbon Impact

What is the situation?

Failure to effectively manage consumption of energy leads to unnecessarily high emissions of CO2 and increased operational costs. Network Rail spends £60m each year on utilities use across its non-traction operational estate and a further £3m in order to comply with carbon legislation. CO2e emissions are in the region of 300,000 tonnes each year.

The rail industry is relatively immature in terms of mitigating operational energyuse, and their resultant carbon emissions, with limited flexibility and agility to monopolise available opportunities. This leads to resource waste, unnecessary emissions of harmful greenhouse gases, and increased operational costs.

Network Rail has a regulated target to reduce CO2e emissions by 11.2 % by the end of CP5. In the first year of CP5, emissions increased by 9.2 % due to an increased portfolio and excessive energy use. Although this increase has been clawed back, we are not where we should be at this point in the control period and we have increasingly diminished opportunity to implement initiatives designed to meet our existing target. Our CP6 ambition is to build on the success delivered during the current control period, and to develop programmes to achieve a 25 % reduction on the CP5 exit position.

Whilst we need to focus on our short-term goal of achieving the CP5 target, there is a need to shape a much longer-term strategy to continually reduce Network Rail's operational carbon emissions in order to contribute towards the goal of the UK rail industry becoming a low carbon railway. Presently, NR's strategic view is – rightly – on our short-term challenges and a long-term strategy is yet to be developed.

The challenges currently facing the UK energy industry, in terms of balancing frequency, supply squeeze and optimising renewable generation present particular problems for the rail network. Supply security is essential to the smooth running of the railway and the risks of black- or brown-outs need to be minimised. The energy industry's response is being implemented through demand side response, capacity mechanism, frequency response and storage. Network Rail needs to become more agile, proactive and responsive if we are to benefit from these new innovations.

Analysis of causes

There is limited capability and capacity embedded within Network Rail's business units to enable swift reaction to the increasing pressures that inertia brings – budget squeeze, missed targets and reputational damage are all key risks in this area. Fragmentation of operations also presents challenges, as Route teams and project teams operate independently, often to the detriment of effective control and mitigation of utilities use.

Energy efficiency initiatives, although generally presenting a robust business case, often demonstrate a payback period of anywhere between 2-8 years. Operating within the boundaries of a 5-year control period therefore presents constraints on investment decisions.

In an understandably risk-averse operation, applying alternative technologies or practices is often difficult to achieve. The overarching priority of the smooth operation of the railway often means that there is a reluctance to change day to day procedures or try alternative products, even those that are commonplace and proven outside of the rail industry.

Priority problems

Specific priority problems

- Limited awareness, capability and motivation across Network Rail's business units.
- Restricted business agility to react to internal and external demands and opportunities.
- Fragmentation of activities around, and management of, utilities and energy related activities.
- Limited funding and/or investment opportunities.
- Need to focus on adopting new technologies or ways of working.
- The need to develop a long-term strategic roadmap for Network Rail to contribute to the goal of becoming a low carbon railway.

Related goals

- An educated and capable workforce which operates in an energy efficient manner.
- Agile business units that are able to react swiftly to maximise benefits.
- Close collaboration between route and project teams, providing a co-ordinated approach to future utility use.
- Easily accessible energy efficiency measures, with funding barriers removed.
- Simple implementation of proven technologies and processes.
- A long-term strategic view with a roadmap to the low carbon railway vision.

Benefits

- Reduced carbon emissions.
- Reduced operational costs.
- Income generation through active participation in initiatives brought about by Electricity Market Reform.
- Increasingly efficient operations.
- Improved reputation as NR strives to deliver a low carbon railway.
- Increasing Network Rail's skills bank and embedding new skills throughout the business.
- Enabling Network Rail to become more resilient and agile to meet future energy needs.

Specific research needs

To address these challenges, and gain the associated benefits, it is expected that R&D actions will need to address the following aspects:

Existing or newly developed technologies (including application of renewable technologies) should be widely implemented to reduce operational energy use at various applications e.g. buildings, points heaters, lineside buildings.

Developing solutions to improve business interfaces to facilitate collaborative working to minimise impact on future operational energy use and resultant costs and carbon.

Enabling innovative frameworks for delivery mechanisms to deploy holistic packages of energy efficiency measures, incorporating alternative funding, maintenance and delivery models.

Developing technology solutions which effectively reduce operational energy use in the railway environment.

Developing technology solutions which incorporate small-scale renewable energy sources, self-generation and storage in the railway environment.

Developing the capability of NR assets to react to opportunities presented through Electricity Market Reform and exploit the income generating mechanisms whilst protecting NR assets and operations.

fig. 1

fig. 2

V2 Using Large Scale Renewable Developments to Enable Decentralised Supply to the Rail Infrastructure

What is the situation?

Opportunities exist to generate electricity close to the rail network, to feed electricity directly into the rail infrastructure. This would reduce costs by eliminating the proportion of the energy bills that deal with transmission and distribution through National Grid, whilst protecting key assets at times of supply uncertainty. Network Rail estimates that annual benefits from implementing renewable schemes could be up to £9m.

What is the challenge?

Electricity generated by wind or solar is increasingly commonplace. The best use of this generation is not to feed it back into the grid for redistribution, but to use it close to the point of generation, so minimising costs associated with transmitting and distributing energy to the point of use. The interfaces between the generation sites and the rail infrastructure networks are not simple, nor is the issue of the intermittency of generation.

Why is it a challenge?

Network Rail owns lots of land on, or around, the network. Some of this land is not suitable for development or traditional use and could be utilised for generation, specifically large solar arrays. Identifying suitable envelopes of land is a challenge due to poor or inaccessible data, and matching with other datasets such as solar efficacy. Further challenges are presented when considering solar as trackside solar arrays could lead to glare affecting driver performance and presenting accident risk.

Potential opportunities are the many tunnels across the rail network, where solar arrays could be mounted without the risk of glare affecting the driver. An example of where this has been successfully deployed is the Paris – Amsterdam rail link, where solar photovoltaic arrays have been installed along a 2 mile stretch of tunnel. Such projects are easily replicable in the UK rail sector.

Wind turbines present a challenge in terms of proximity to lineside, considering topple distance, shadow flicker etc. This, however is not insurmountable as the right site could still present significant opportunities for private-wire arrangements.

Matching demand with output may be difficult, although particularly for wind could be overcome by incorporating battery storage.

Commercial organisations who could develop private land adjacent to the railway are available to assist, and would then sell the electricity generated to Network Rail. The challenge here is to understand the best value option in these situations.

Priority problems

Specific priority problems	Related goals	Benefits
• Available land for development of large-scale renewables is not known at present. • Lack of in-house capability to assess potential sites. • Lack of knowledge of how risks such as glare or flicker may impact safety on the railway. • Matching demand with output. • Lack of in-house capability to assess options for commercial offers from third party developers.	• An understanding of Network Rail's available land portfolio and its generation capacity. • A clear understanding of the potential risks of deploying large scale renewables close to the rail infrastructure. • Effective solutions to match demand and output. • Identification of best value offers from third party developers, so that opportunities can be maximised.	• Reduced carbon emissions by minimising grid-delivered electricity and utilising renewable generation. • Increased knowledge of renewable technologies and how they can directly interface with the rail network. • Ability to replicate projects to widen our scope of generation. • Cost savings through elimination of transmission and distribution costs. • Potential generation of revenue • Improved reputation by publicising positive results and case studies.

Specific research needs

To address these challenges, and gain the associated benefits, it is expected that R&D actions will need to address the following aspects:

- Deployment of large scale renewable generation could reduce our reliance on National Grid whilst reducing costs and carbon emissions.
- Developing solutions to enable private-wire generation directly to the traction or non-traction infrastructure.
- Gaining intelligence in-house to enable exploitation of third party offers to maximise benefits to NR.

fig. 1

fig. 2

Adapting the Railway for Improved Resilience against Future Weather Conditions as a Result of Climate Change

Priority problems

Weather-related impacts have caused, on average, 1.5million delay minutes per year since 2006.

Wind and flooding have by far the biggest impact on the railway. Addressing the problems outlined below will reduce delay minutes and associated costs, cancellations, repairs now and in the future.

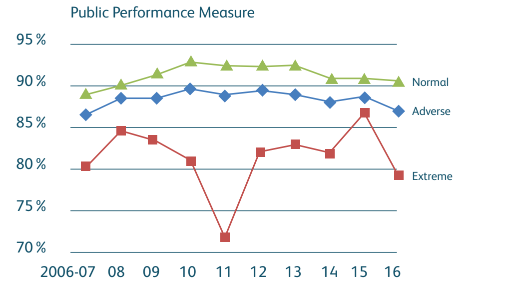
Specific priority problems	Related goals
• Vegetation growth and biodiversity Climate change will alter growth and distribution of vegetation, biodiversity and pests/diseases. This could make managing vegetation growth more challenging and have both negative and positive impacts upon efforts to support biodiversity. Delay minutes 2006 – 2016 Wind: 19.3m; Adhesion: 9.1m	• Understand how changes in species/vegetation could affect current lineside management approaches. Identify new ways of using vegetation to enhance safety and performance. • Understand how climate change might impact our current efforts to manage biodiversity.
• Flooding Winter rainfall is projected to increase significantly as a result of climate change with peak river flows increasing from 5 - >100 % depending on catchment. 40 % of track is already at high/medium risk of flooding. Delay minutes 2006 – 2016: Flooding 18.3m	• Identify new technologies and approaches to enhance the resilience of the railway system. Including reducing the impacts of flooding upon individual assets.
• Frequency of storms The cumulative impact of wind, heavy rain and lightning has a significant impact on the railway. The intensity and frequency of storms may change in the future, this could amplify risks to an already vulnerable system. Delay minutes 2006 – 2016 combined lightning, flood and wind: 40.7m. Storm Doris on 23 February 2017 cost £7.4m in Schedule 8 delays in one day.	• Enhance forecasting and planning in advance of storms. • Identify new approaches to managing cumulative impact to assets during storm events (e.g. remote monitoring).
• Lightning Lightning can cause significant disruption to signalling and electrical equipment. Climate change is likely to affect the frequency and intensity of storm events although the impact on the incidence of lightning strikes is uncertain. Delay minutes 2006 – 2016 Lightning 3.1m	• Understand where and how the frequency and intensity of lightning strikes might change in the future. • Ensure that the Digital Railway is not impacted by lightning and changing electrical/magnetic atmospheric conditions (e.g. GPS and other non-hardwired assets). • Increase resilience of signalling, electrical and other assets to impact of direct strikes and surges and other secondary impacts from lightning strikes elsewhere.
• High temperatures An increase in mean temperatures, including hot and very hot conditions, and reduction in the diurnal temperature range will amplify impacts already experienced during high temperatures and reduce the time available for maintenance activities (due to workforce heat stress, rails being too hot to handle for longer periods etc). Delay minutes 2006 – 2016: Heat 0.6m	• Reduce mechanical and asset failures in high temperatures looking at the whole system including track, switches, clips, OLE, signalling rolling stock etc. • Develop more efficient and innovative approaches to maintenance to reduce the impact of heat stress on maintenance activities.

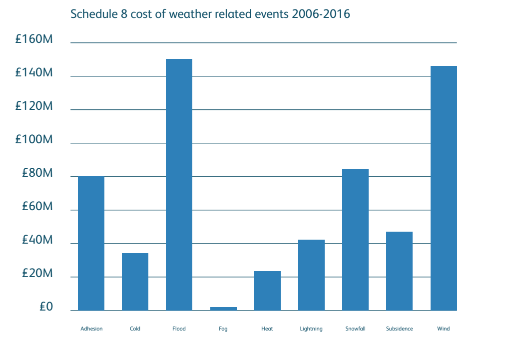
NetworkRail

What is the situation?

Adverse and extreme weather conditions have a significant impact on the reliability of assets and on the performance and safety of the railway. Weather impacts cost us £50-£100m per year in delays and cancellations alone. However, the overall cost is much higher when weather-specific maintenance and repair costs are included. Adverse weather conditions have resulted in an average 2-3 % reduction in Public Performance Measure (PPM) performance across the railway network compared with normal weather conditions over the past decade. The impact of extreme weather can vary significantly year-by-year.

Climate change is projected to increase temperature and precipitation and deliver more disruptive weather events such as storms. It will affect our understanding of risk as historic patterns of likelihood and severity shift, thereby amplifying the impact of weather on the railway. As coping thresholds are breached, risk levels may reach unacceptable levels and becoming resilient will be more challenging. Extensive knowledge of assets and awareness of weather vulnerabilities and the long-life nature of the majority of assets means that we know broadly how climate change is likely to impact the railway. The challenge is to adapt by finding new ways of working, potentially radically shifting what has been standard practice, in order to maintain an acceptable level of risk when faced with increasingly extreme weather conditions. We need to identify and test new asset designs, technologies and approaches. Future proofing the renewals, enhancements and infrastructure projects that we are building today and provide life-cycles that span many years.





Specific research needs

This challenge seeks research into new ways of designing assets (infrastructure, rolling stock etc), operating the railway, undertaking maintenance and inspections etc. which would result in a measurable improvement in resilience.

Network Rail holds significant data relating to costs and delays from past weather incidents and asset reliability which can be made available to support analysis. Pilot projects to trial new approaches and technologies can also be arranged.

Specific Research and Technology Questions

With consideration as to how climate change will affect the frequency, severity, and potential location of adverse and extreme weather events, and the associated cost benefit of adaptation:

- How can assets/ infrastructure be redesigned to enhance reliability, prevent and reduce weather-related impacts?
- What technology can enable a shift in the way things have been done in the past to prevent/reduce the impact of weather on operations and assets?
- What can be done to enhance preparation for extreme weather events as well as prevent incidents from occurring?
- What can be done to improve response and recovery times following incidents to reduce delays and cancellations?
- What operational changes can be made to reduce the impact of climate change (e.g. new approaches to maintenance, timetabling, track stressing etc).
- Considering the railway as a system of systems, what changes can we make in one area which might have knock-on benefits in the resilience of others?
- What is the cost benefit of the above measures including the value of the loss avoided in perpetuity and payback?

This challenge is intentionally broad in order to facilitate innovation. Network Rail is willing to discuss and consider additional research and technology questions based on the merits of the idea and potential associated benefit.

Expected impact & benefits

Enhancing resilience of the railway will have a significant long-term positive impact on safety, performance and finances. Unlocking new ways to prevent or significantly reduce particular weather-related impacts on the railway could eliminate the need for Temporary Speed Restrictions and prevent incidents causing delay and damage to infrastructure. Current costs are in excess of £50-100m per year and without adaptation, costs will increase as assets struggle to operate under extreme conditions.

Improving Vegetation Management Decision Making

What is the situation?

Failure to provide and maintain green infrastructure beside the rail network leads to significant liabilities including:

- Increased environmental, operational and safety risks due to overgrown vegetation (fig.1).
- Greater performance costs and increased disruption.
- Increased risk to spread of invasive, non-native species (fig.4).
- Poorer customer and community relations/increased complaints from neighbouring properties (fig.3).
- Increased capital and management costs to create desirable lineside structure (fig.2).
- Reduced biodiversity.
- Risk of breach of legislation.

This can lead to significant costs and missed opportunities, including:

- £100m cost annually to the UK economy as a result of vegetation impacts on train performance.
- 25,000 complaints per annum relating to vegetation management.
- 200 % Traditional drainage solutions cost twice as much as sustainable drainage systems.

fig. 1

fig. 4

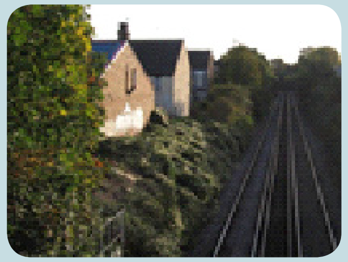


fig. 3

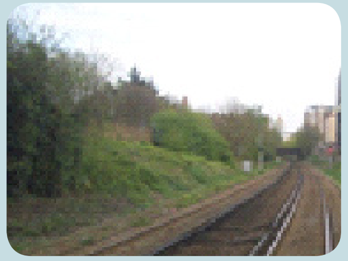


fig. 2

Scope

The ability to make timely and effective decisions is a key factor in managing the assets in accordance to policy and strategy. Whole life costs must be considered in soft estate performance and management assessments to secure more resilient, efficient and cost effective hard infrastructure.

The enablers to supporting better decision making are:

- Data collection, analysis and storage.
- Decision support tools.
- Modelling.
- System approach.
- Training, briefing and awareness.

Providing a solution to the issues highlighted for each individual enabler (see Analysis of Causes) will allow for a safer, more reliable and efficient asset.

Analysis of causes

Priority problems

Specific priority problems

- Mapping data required to enable collaboration with external organisations who have environmental and ecological datasets.
- Lack of decision support tools.
- Tools and datasets needed to manage, view and map vegetation as a system (including a workflow management system).
- Investigations into novel vegetation management techniques to counter any reduction in pesticide use.

Related goals

- To produce a top-down whole life cycle and cost model for vegetation by the end of CP7.
- To produce a bottom-up decision support work-bank tool by the end of CP6.
- Habitats and associated heat maps of potential for protected species identified by the end of CP6.
- The right green infrastructure in the right place by the end of CP7.

Benefits

- The right green infrastructure in the right place along linear infrastructure networks could bring significant benefits including:
  - Enhanced local character and user experience.
  - Revenue generation opportunities and reduced waste from verge harvesting for biomass energy.
  - improved air quality, drainage management and carbon capture.
  - Enhanced biodiversity corridors and quality of life.

Specific research needs

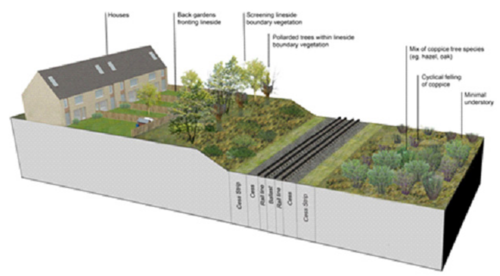
To address these challenges it is expected that R&D actions will need to address the following aspects:

- **Models and top-down whole life modelling tool**
  How can top-down whole life cost modelling of vegetation be achieved? What new models need to be developed and combined with existing models to account for factors such as degradation, capability analysis, flood risks due to land use change, climate change, weather resilience, vegetation growth rates, impacts of pests and diseases, etc.? What models already exist in utility or agricultural industries that can be transferred to use on the rail infrastructure?

- **Decision support tools**
  How can current and new processes be managed better with decision support tools? What is required to develop a live bottom-up work-bank tool and how would this integrate with existing systems? What methods and techniques exist in other industries managing vegetation for products or to improve asset resilience? How do other industries improve the competence and capability of non-technical staff to support them in their roles?

- **Tools and datasets to manage, view, map vegetation as a system**
  How can we map and view vegetation as a system? Tools and datasets are required for the management of vegetation from a holistic systems approach. The developed tools should support the decision-making process and allow for timely interventions providing both whole life cost and safety, environmental benefits whilst taking into account the length of the life cycles of the systems involved.

- **Investigations into novel vegetation management techniques to counter any reduction in pesticide use**
  What novel techniques are available to enable targeted application of pesticides at lower dosage rates? What manual and mechanical methods can be employed to improve the efficacy of existing or novel pesticides? Are there techniques in development that can provide equal or better control of unwanted plant species when compared with existing techniques? What novel bio-control techniques are applicable to use on the railway infrastructure?



Schematic urban lineside vegetation structure' fig. 5

Electrical Safety

What is the situation?

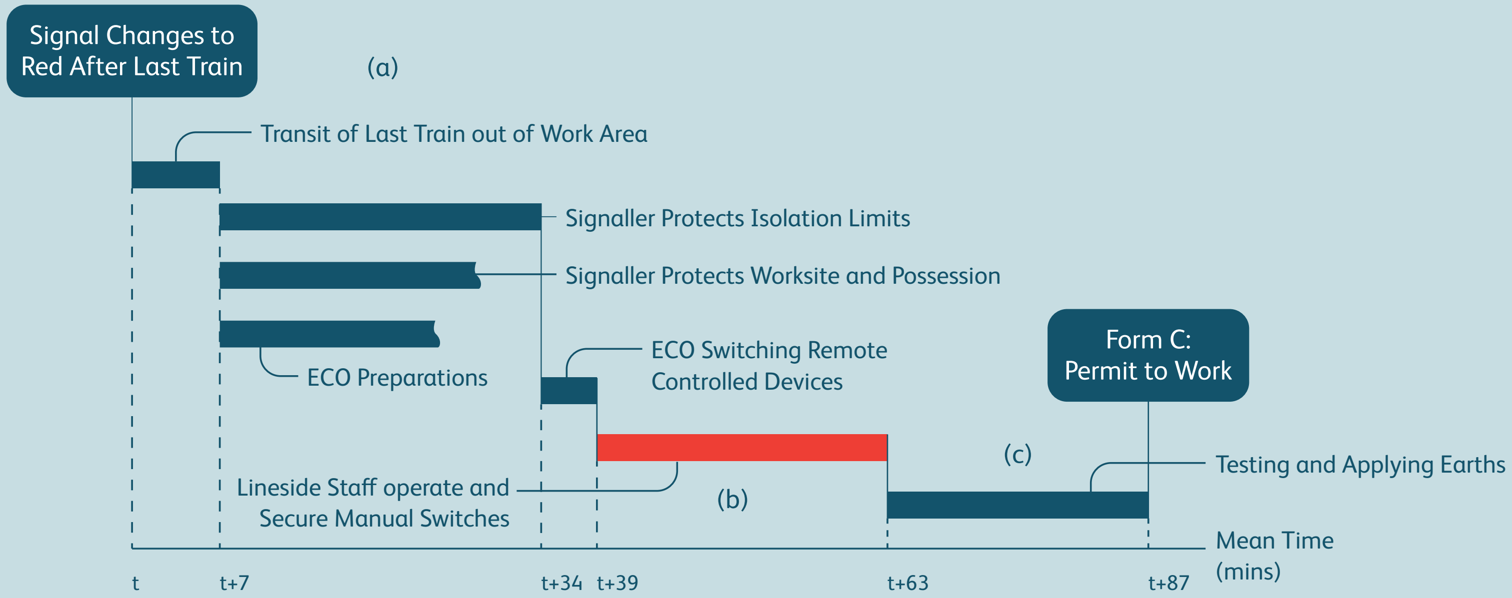
In order to facilitate maintenance works NR takes more than 35,000 isolations per year, approximately 2/3 on the AC network and 1/3 on the DC network. The railway electrical environment provides some unique electrical safety challenges, from the number of parallel circuits, to the arrangement of cross-track feeds and discrete overhead line features such as Section Insulators and Insulated Overlaps, the electrical environment is complex.

Without a technology pathway for development for new tools, equipment and Automatic Isolations and Earthing (AIE) new a.c electrification projects will be exposed to unnecessary safety and compliance risk and extended isolation process on a piecemeal basis, leading to increased staff requirements, or else, reduced maintenance access windows.

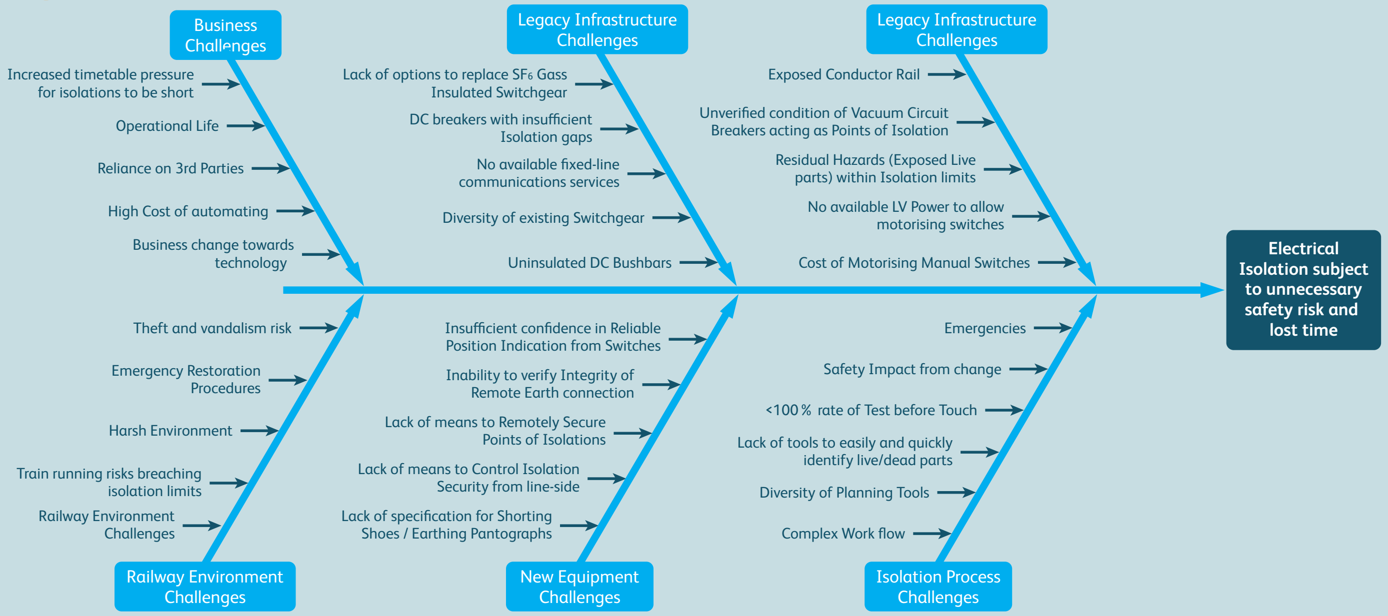
In terms of tools, improvements in live line testers may offer the opportunity to reinforce process and support better identification of live parts; likewise development of innovative means of identifying live parts can contribute to improving electrical safety.

As for equipment, the historical use of Vacuum Circuit breakers as points of isolation, and use of other switches without security, will not be acceptable in future. A reversion to manually operated switches and padlocks alternatively presents an extension to the mean time it takes to set up an isolation and consequently a loss of maintenance access time.

Automation can unlock significant benefits compared to today's manual isolation processes, in terms of the safety and speed at which a compliant isolation can be implemented, thereby helping NR to achieve greater access time to undertake works, however, its deployment comes with a number of challenges.



Analysis of causes



Scope

The overall scope of the challenge is to explore the potential for new technologies to support enhanced safety across the electrified network.

Supporting this are:

- Developing improved knowledge of discrete contact system features and developing new components to reduce the prevalence of exposed, live parts.
- Enablers to support the widespread deployment of improved isolation processes and technologies, across both new and legacy electrification systems. These enablers include retrofitting automation to existing non-motorised disconnectors at remote locations.
- New tools to support improved isolation processes and assist in the demarcation of safe working limits.

Priority problems

Specific priority problems	Related goals	Benefits
• Develop new techniques, equipment and understanding to improve the electrical safety of legacy assets.	• Improve the industry's understanding and optimise the dynamic performance of discrete features in the OLE, i.e. Section Insulators and Neutral sections. • Design and development of a Section Insulator with Basic Insulation for 25kV (Compliant to BS EN 50124). • Design and development of Conductor Rail with Basic Insulation (apart from Contact Surface).	• In the a.c. system: improved reliability of the contact system, fewer de-wirements, in conjunction with a new Section Insulator contributes to the improved electrical safety. • In the d.c. system contributes to improved electrical safety by reducing the risk of contact with exposed live parts.
• Development of technologies to support automated isolations and Earthing.	• Development of Remote Securing for a.c. and d.c. Points of Isolation. • Retrofit position indication and motorisation for 25kV switches. • Identification of Power and wireless communications technologies for switches at remote sites (e.g. power harvesting). • Remote Earth Circuit verification, to prove the effective application of a remote earth.	• Allows isolations set-up to be automated, thereby achieving faster set-up. • Contributes to improved safety and compliance by allowing isolations to be secure and with confirmed operation of circuit main earths, thereby avoiding potential safety risks from inadvertent re-energisation.
• Development of Supporting Tools and Equipment for Isolations.	• Design and development of Live line testers with data logging facilities (i.e. GPS, time stamp, etc.). • Design and development of Augmented reality system for identifying live/earthed & isolated conductors.	• Ensures life-saving rules are followed by supplying an easily used and effective toolkit for isolations. • Ensures people do not inadvertently encroach live parts by making identification of live components simple.

Expected impact & benefits

- Improved safety and reliability performance from the contact system.
- Reduced likelihood of electrical safety incidents during maintenance or project works.
- Improved compliance to the Electricity at Work Regulations (EaWR, 1989).
- Improved safety and compliance with faster isolations.

Intelligent Assets and Condition Monitoring

What is the situation?

Our challenge is to improve the Asset Condition Monitoring process and implement it across the network. One of the main goals is to enable us to make more informed decisions about maintenance and renewals. Improving asset management through Intelligent Asset and Condition Monitoring will deliver a safer, more reliable railway that costs less to manage in the long-run.

Based upon consideration of asset failure characteristics, and the experience of European railway operators who have implemented condition monitoring equipment, we believe that a significant percentage of failures can be prevented by an effective Intelligent Asset and Condition Monitoring process. It is an area that we have focused on as a key enabler to move from a 'find and fix' approach to one of 'predict and prevent'. In terms of E&P equipment, the failures that have been identified as having the potential to be prevented by the Intelligent Asset and Condition Monitoring system include the following Overhead Line Equipment (OLE) failures:

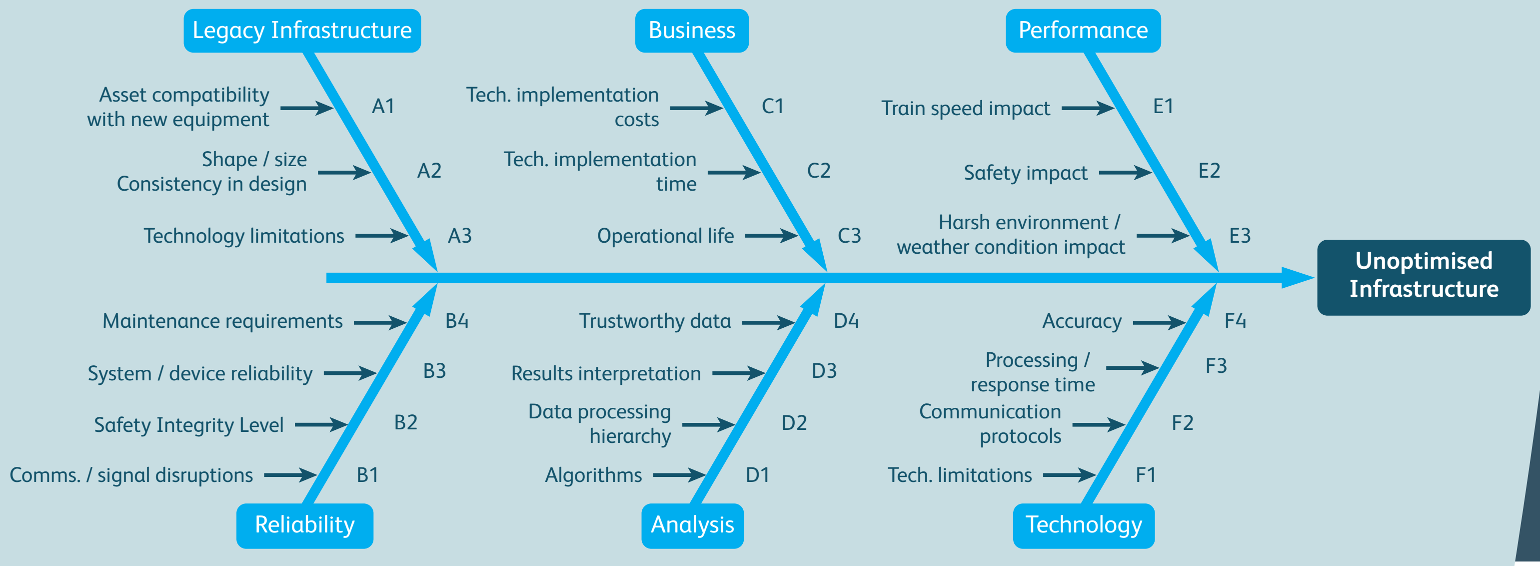
- Damaged droppers and dropper wires.
- Damaged conductor wire.
- Broken or displaced Insulators.

Currently we are experiencing an increasing trend of dropper failure due to fatigue of the dropper wire. Simple analysis of overhead line dropper failures provides the evidence to highlight the benefits Intelligent Asset and Condition Monitoring could generate if implemented. In the majority of cases it is expected that the failure's root cause could be prevented by utilising a system of devices such as ruggedised train roof mounted cameras and sensors.

R&D activities are required to unlock the following ambitions:

- To reduce the maintenance cost and time-related to E&P infrastructure failures.
- To reduce the number and duration of train delays/cancellations related to E&P infrastructure failures.
- To improve timetable reliability due to more reliable infrastructure.
- To improve the asset management process.

Analysis of causes



Scope

The overall scope of the challenge is to investigate the potential for new technologies and techniques to support the ambition of Intelligent Asset and Condition Monitoring. The enablers for this are:

- Network-wide asset data capture and inspection. Utilising in-service vehicles and portable monitoring equipment.
- Intelligent Assets that inform the Asset Management process.
- New techniques to analyse and translate monitoring data to unlock 'predict and prevent' maintenance activities.

Priority problems

Specific priority problems

- Development of new tools, techniques, equipment and understanding to improve the reliability of E&P assets as part of the Contact System and Distribution infrastructure.

Related goals

- Improve the industry's understanding of the failure mechanism and optimise the reliability and design life of droppers.
- Improve the efficiency and accuracy of overhead line equipment asset data capture through:
  - Pattern recognition technology on in-service vehicles;
  - Pantograph gauging of OLE and fixed infrastructure;
  - Real-time object recognition and analysis for Pantograph cameras.
- Portable Vacuum bottle integrity monitoring
- Design and development of a new non-contact manual gauging tool for conductor rail. The train-borne fleet cannot cover 100 % of the network and the industry needs the capability to carry out measurements manually.

Benefits

- Reduction in the number of dropper failures incidents, and associated train delays.
- Automated inspection process, which is quicker, safer and more cost-effective.
- Increased understanding of Contact System condition compliance in line with Asset Policy as a result of better data coverage and accuracy.

Specific priority problems

- Development of new tools, techniques, equipment and understanding to improve the efficiency and effectiveness of the Asset Management process.

Related goals

- Design and development of automated earth testers for proving earth farms for Signalling Power equipment.
- Design and development of Intelligent Insulation Monitoring for Signalling Power Supplies.
- Remote detection of parted conductors including:
  - Parted wires in the Contact System (e.g. Auxiliary wires);
  - Discontinuities in Return Screening Conductors;
  - Measurement of conductor tension in station areas and the facility to automatically turn off the power under a wire break situation.
- Development of algorithms for high accuracy fault location, to support faster maintenance response to the correct location, in the a.c. network
- Development of algorithms for remote detection of high impedance and arcing faults on the a.c. network.
- Investigation on the use of QR codes, or similar technology, for recognition of components/ assemblies/ design for use on site by staff.

Benefits

- Ensures life-saving rules are followed by supplying an easily used and effective toolkit for isolations.
- Ensures people do not inadvertently encroach live parts by making identification of live components simple.

Expected impact & benefits

- Reduced E&P maintenance cost and time.
- Reduction in the number of train delay minutes/cancellations related to E&P infrastructure failures.
- Improved timetable reliability due to more reliable infrastructure.
- Improved asset management process.

Intelligent Assets and Condition Monitoring

What is the situation?

Our challenge is to improve the Asset Condition Monitoring process and implement it across the network. One of the main goals is to enable us to make more informed decisions about maintenance and renewals. Improving asset management through Intelligent Asset and Condition Monitoring will deliver a safer, more reliable railway that costs less to manage in the long-run.

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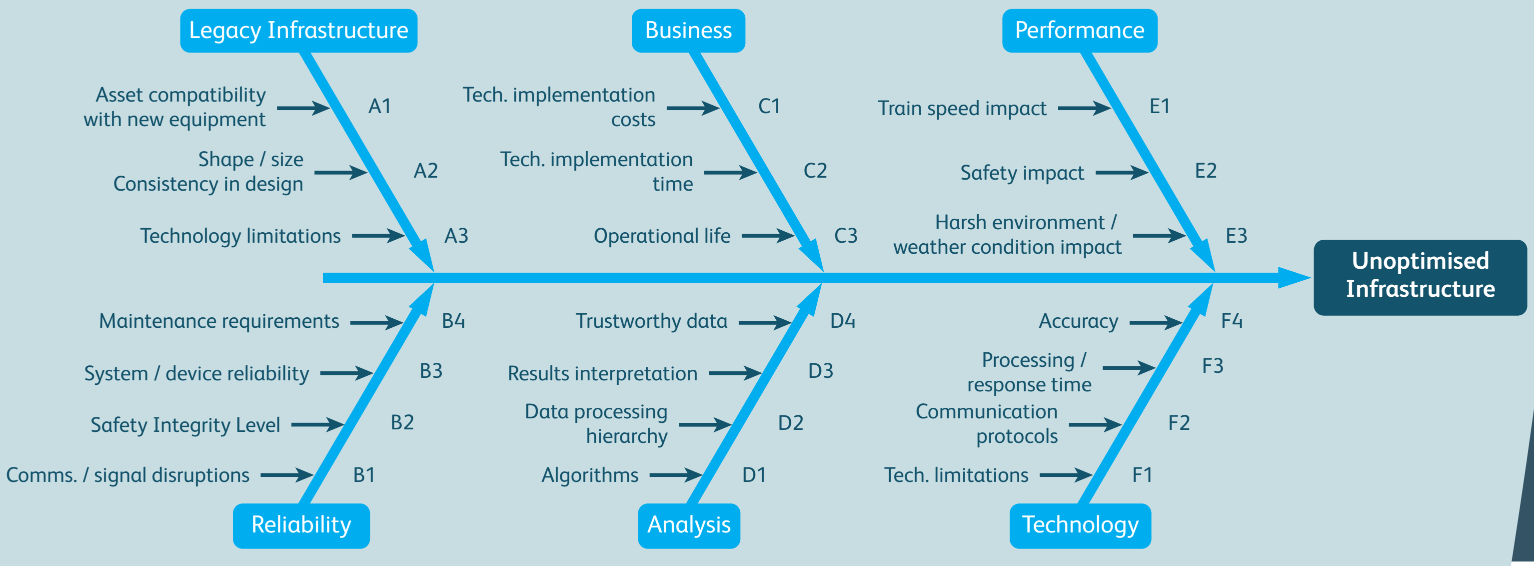
Analysis of causes



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Priority problems

Specific priority problems

- Development of new tools, techniques, equipment and understanding to improve the reliability of E&P assets as part of the Contact System and Distribution infrastructure.

Related goals

- Improve the industry's understanding of the failure mechanism and optimise the reliability and design life of droppers.
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- Design and development of a new non-contact manual gauging tool for conductor rail. The train-borne fleet cannot cover 100 % of the network and the industry needs the capability to carry out measurements manually.

Benefits

- Reduction in the number of dropper failures incidents, and associated train delays.
- Automated inspection process, which is quicker, safer and more cost-effective.
- Increased understanding of Contact System condition compliance in line with Asset Policy as a result of better data coverage and accuracy.

Specific priority problems

- Development of new tools, techniques, equipment and understanding to improve the efficiency and effectiveness of the Asset Management process.

Related goals

- Design and development of automated earth testers for proving earth farms for Signalling Power equipment.
- Design and development of Intelligent Insulation Monitoring for Signalling Power Supplies.
- Remote detection of parted conductors including:
  - Parted wires in the Contact System (e.g. Auxiliary wires);
  - Discontinuities in Return Screening Conductors;
  - Measurement of conductor tension in station areas and the facility to automatically turn off the power under a wire break situation.
- Development of algorithms for high accuracy fault location, to support faster maintenance response to the correct location, in the a.c. network
- Development of algorithms for remote detection of high impedance and arcing faults on the a.c. network.
- Investigation on the use of QR codes, or similar technology, for recognition of components/ assemblies/ design for use on site by staff.

Benefits

- Ensures life-saving rules are followed by supplying an easily used and effective toolkit for isolations.
- Ensures people do not inadvertently encroach live parts by making identification of live components simple.

Expected impact & benefits

- Reduced E&P maintenance cost and time.
- Reduction in the number of train delay minutes/cancellations related to E&P infrastructure failures.
- Improved timetable reliability due to more reliable infrastructure.
- Improved asset management process.

Smarter, more Efficient Electrification

What is the situation?

Electrical power demand on the railway continues to increase as a result of expanding electrification and longer, more frequent and more power intensive trains.

Approximately 40 % of the British railway network is electrified, comprising 25 kV a.c. (two-thirds) and 750 V d.c. (one-third) systems supplying traction power to trains. The benefits of expanding the electrified network will be realised as part of a rolling electrification programme. However, the business justification for electrifying less frequently used lines hangs in the balance, leaving nearly half of the railway network reliant on self-powered trains.

In 2015-16, the UK railway traction electricity demand was 3.4 TW/h, making us one of the largest single consumers of electricity in the UK.

We are progressing Smart Grid technologies (such as IEC 61850) as well as energy harvesting, storage and recycling (regen. braking) to reduce costs and demand.

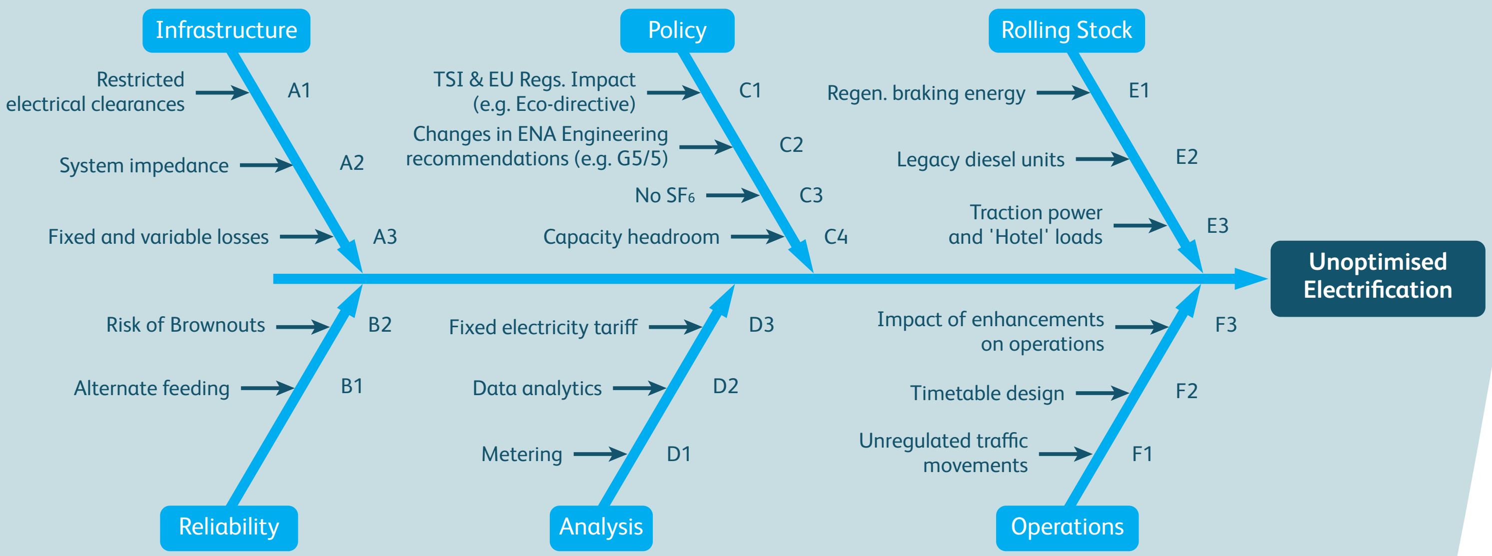
R&D activities are required to further unlock the following ambitions:

- To reduce the cost of electric traction infrastructure.
- To grow the capability to increase the proportion of electric traction use.
- To improve the management of electrical energy demand.
- To improve the efficiency of electrical energy.

Our challenge is to improve the electrification infrastructure operation, economically and efficiently, keeping sufficient capacity headroom maintained. An enabler to achieving this objective, and satisfying our licence condition, is further development and implementation of smarter, more efficient electrification systems. This includes new electrification, as well as, modifications to legacy infrastructure where appropriate.

Appendix 7 - Core and further options

Analysis of causes



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Scope

The overall scope of the challenge is to investigate the potential for new technologies and techniques to support the ambition of smarter, more efficient electrification. The enablers for this are:

- Optimised design and performance of electrification equipment and systems.
- Real-time understanding and control of how electrical energy flows in the network.
- Electrical distribution assets which utilise modern materials and methods to reduce electrical losses.

Priority problems

Specific priority problems	Related goals	Benefits
• Development of new tools, techniques, equipment and understanding to reduce the cost of electrification.	• Design and development of Compact Substations (e.g. replacement of Sulphur hexafluoride (SF6) with alternative gases in Gas Insulated Switchgear and progression of Solid Insulated Switchgear utilising disconnectors with sufficient air-clearance). • Improve the industry's understanding of optimising Discontinuous Electrification (e.g. onboard storage, charging, pantograph raising/lowering) to avoid expensive civil alterations associated with accommodating the contact system in areas of restricted electrical clearances (e.g. bridges and tunnels). • Development of automated Overhead Line Equipment design tools, i.e. efficient allocation design tools with integrated survey platform in order to minimise data processing.	• Greater capability to increase the proportion of electric traction on the network, including freight services. • Better value for the taxpayer and better for the environment.
• Development of technologies which facilitate and improve the management of electrical energy demand.	• Development of Power Quality and Smart Metering technologies for the industry, including linear transducers and harmonic monitoring capability for high-frequency harmonics. • Development of Smart Network components, including power electronic technologies, Automatic Voltage Control and energy harvesting, storage and recycling (regen. braking).	• Compliant electricity supply industry connections and greater alignment with electricity supply industry best practice. • Cost-efficient acquisition and smarter use of electricity.
• Development of equipment to improve the efficiency of electrical energy distribution.	• Design and development of high-efficiency Auxiliary and Rectifier Transformers to meet (auxiliary) or be designed to the equivalent standard of (rectifier) the EU Eco-directive; investigations to include the robustness of transformers built to high-efficiency designs and special measures for cooling circuits to increase efficiency. • Research into the use of composite materials for conductor rail to reduce wear rates (linked to impedance) and extend asset life.	• Greater compliance with EU Regulations and alignment with electricity supply industry best practice. • Reduced electricity bill and greater green credentials for the rail industry.

Expected impact & benefits

- Reduced cost of electrical traction infrastructure.
- Greater capability to increase the proportion of electric traction.
- Improved management of electrical energy demand.
- Improved efficiency of electrical energy distribution.

V2 Preventing an Incident or Near Miss at a Level Crossing Due to User Behaviours

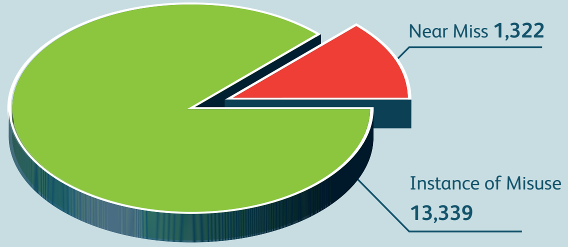
NetworkRail

What is the situation?

Collisions at level crossings are the largest single train accident risk. Between April 2006 and March 2016, eighty-six accidental fatalities occurred at level crossings. Although the number of occurrences has decreased over this period, we haven't been able to eradicate the problem. Four accidental fatalities have occurred since April 2016.

It is part of our long-term strategy to reduce the likelihood of such incidents. Our primary objective is to close as many level crossings as possible. Where a closure isn't achievable, we will drive down risk through the introduction of advanced technology. Our research studies, including the Willingness to Wait assessment, are helping us to better understand user behaviour but there is more work to do.

Level Crossing Incidents since 2012
(Recorded 30.11.2015)



From 2015 to 2016, Network Rail incurred costs of £12.3m from all types of events at level crossings.

The challenge of communicating the risks of level crossings to the public remains. Empowering users to act safely when crossing the railway while also understanding how we can improve our assets, and reduce risk, is our key focus at level crossings.

Analysis of causes

How we cross

Using a mode of transport:

- Cars.
- Vans and lorries.
- Bicycles and motor bikes.
- Farm vehicles.
- Buses.
- Mobility scooter.
- Horse.

Categories of people walking onto the crossing:

- Adults.
- Children.
- Young adults.
- Dog walkers.
- Farm workers.
- People with mobility issues (or disability).

1 Perception of Risk

A. Familiarity with Crossing
➔A2: Effects of irregular or untimetabled service
B. Prior education and experience
C. Failure to hear or sound whistle
D. Gates left open

2 Distraction During Traverse

A. Using technology whilst walking
B. Pets (e.g. Dog running onto track)
C. Sat Nav / Hands-free systems

3 Communication

A. Obscured and unclear signage
B. Obscured crossing (vegetation)
C. Poor quality communication with signaller
D. Difficulty hearing train horn
E. Language barriers
F. Current methods assume prior knowledge

4 External Influences incl. Design

A. Park cars/backed up traffic/overtaking
B. Poor road adhesion
C. Weather conditions (fog / sun glare)
D. User running late / high workload
E. Level crossing faults
F. Peer-pressure / bravado
G. Speed of traverse
H. Getting stuck on crossing / being injured on crossing

Priority problems

Specific priority problems

- Improving the protection provided at level crossings through technological innovation.
- Enhancing communications with both unfamiliar and existing users of level crossings to educate the public and raise awareness of risk.

Related goals

- Understand how we can best inform users of the risks posed by misusing a level crossing.
- Overcome variable train approach speeds to deliver a consistent warning time to crossing users.
- Zero harm at crossings, including near miss trauma.
- By 2025 telephones will not be the primary means of protection at any of our user-worked crossings.
- By 2025 all whistle boards will either have been eliminated or supported by automatic user-based warnings.

Benefits

- Reduction in fatalities and incidents of all nature at level crossings.

Specific research needs

To address these challenges it is expected that R&D actions need to address the following aspects:

Understanding the Level Crossing User
A deeper understanding of user behaviour at crossings is needed. What makes users do what they do? What factors contribute to their decision-making process? How can we inform users of the unique risks related to the railway environment at a level crossing? What do users consider an effective warning system?

Warning period and train arrival consistency
What does a consistent warning period and train arrival time have on the user's 'willingness to wait'? How long should a consistent warning time be? What technologies are currently available to predict train arrival time and provide a consistent warning period? Can a solution be developed that will determine the exact train location and level crossing arrival time?

Emerging social behaviours and distractions e,g satnav, smart phones, headphones and other forms of mobile technology
Assessment and impact of emerging social behaviours in terms of risks posed and mitigations needed. How can we 'future proof' level crossings so that they continue to protect users effectively?

Technologies to address behaviours
What type of technology is most suitable to address the issues raised above?

Lineside Asset Management

What is the situation?

The management of the lineside principally deals with:

- Management of vegetation along the railway and within the boundary to reduce or avoid risk to the railway
- Assuring a boundary is provided to satisfy a legal requirement and avoid trespass or incursion.

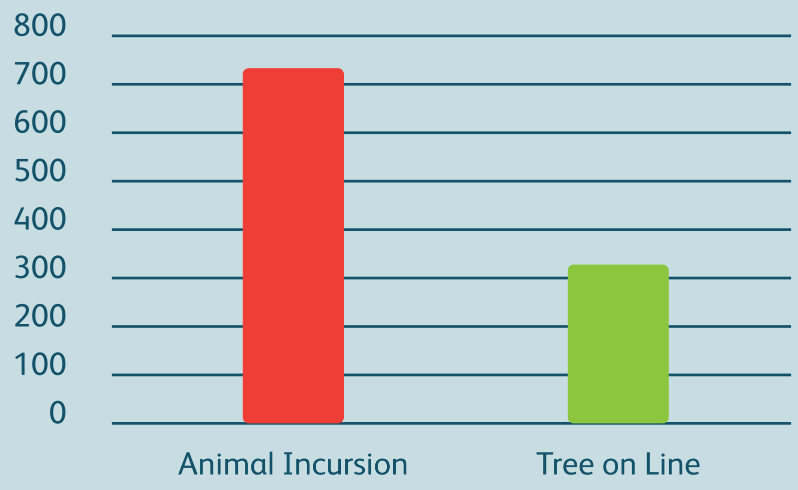
The Lineside asset uses Ellipse for its work bank management system and for our asset database. Weaknesses have been identified in this method and the overall suitability of Ellipse's asset-inventory depository, vegetation reporting system and boundary management hasn't been fully explored or tested. Current practices for capturing asset information are inefficient and rely on manual inspection. For example, there are no known processes for capturing information regarding life expectancy and degradation measures.

We do not currently have a process to record asset behaviour. For example, what is expected performance from the asset? (growth & decline).

We are unable to assess external influence with regard to changes in adjacent land management and influences from environmental conditions.

A lack of understanding of the asset has led to many incidents across the network. Some have resulted in damage to infrastructure or vehicles.

Lineside Incidents P1 to P7, 16/17



Priority problems

Specific priority problems

- We seek systems to provide insight so that failure can be prevented. We are alerted when the asset fails or is about to fail.
- We are unable to demonstrate the configuration and condition of our asset.
- At best, we react to recover the railway without investigating the root cause.
- We lack the ability to gather a full inventory of the asset, the risk of failure and its associated lifecycle.

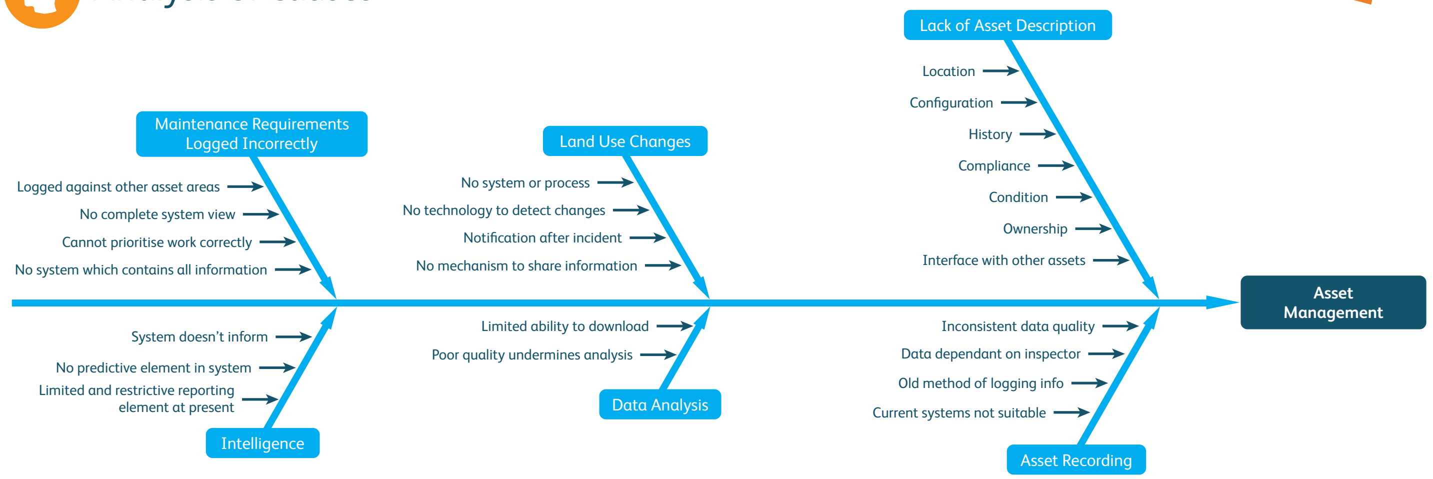
Related goals

- A mechanism for understanding root cause and the appropriate prevention measures.
- An efficient system for updating the asset.
- Provision of an asset register for lineside.

Benefits

- 'One version of the truth' in that all the asset and work carried out on it, is recorded in one place.
- Up to date asset record that can report condition and risk ranking.
- The system is efficient at accepting information from inspection, survey, remote monitoring and LIDAR data models.
- Improved performance as a result of better-timed intervention.

Analysis of causes



Scope

To satisfactorily provide for a linear asset but with considerable variation in its composition. Not all elements must be recorded but the system must be adaptable to capture key information along with varying extents. The network is segmented to reflect the output of inspection as well as produce reports on health or compliance within standardised units (mainly 1/8ths of a mile).

The need to log work for vegetation which affects other assets and the information is provided in varying formats and configuration.

Improved means of data entry, current practices rely on availability of resources to be able to update ellipse from paper forms returned to planners and system support managers.

Success relies on the system being efficient and adopted by the inspector/surveyor. The system relies on Managers having sufficient knowledge to manage the asset updates within a data storage system within CITRIX (Field data manager).

Relies on up to date information captured during the inspection, without any condition measures and history. It is difficult to endorse for decisions support.

Inspections are required after an incident or in anticipation of one. We need indicators so that preventative measures can be adopted.

Data gathered from LiDAR survey is not currently transferable into ellipse to update the asset register

To address these challenges it is expected that R&D actions will need to address the following aspects:

- What asset-management systems are used, externally from Network Rail, for the lineside or its equivalent?
- What capability is available (again external to Network Rail) to carry out this assessment? We are looking for a more flexible and advanced capability for digital input and management of an asset database.
- What examples are carried out on other companies of use of systems that enable proactive, successful management of our lineside elements?
- Have other Network Rail departments evaluated or used ELLIPSE for the full range of requirements?
- What technology is available to alert of a change in risk to a lineside asset?
- Can this technology capture necessary information and data on a remote basis?
- What experience is there of using 'data, information, knowledge, wisdom' principles to asset management methods in line with our lineside challenge?

Lineside Boundary Management

What is the situation?

It is the railway's legal responsibility to ensure boundary measures are in place to prevent human and livestock incursion. We often fall short of our obligations where boundary measures are expected to perform in hostile environments without sufficient intervention. Preventative measures are not consistently adopted. The design or condition of the boundary measure is not always appropriate for the risk presented by the adjacent land use.

Animal incursion

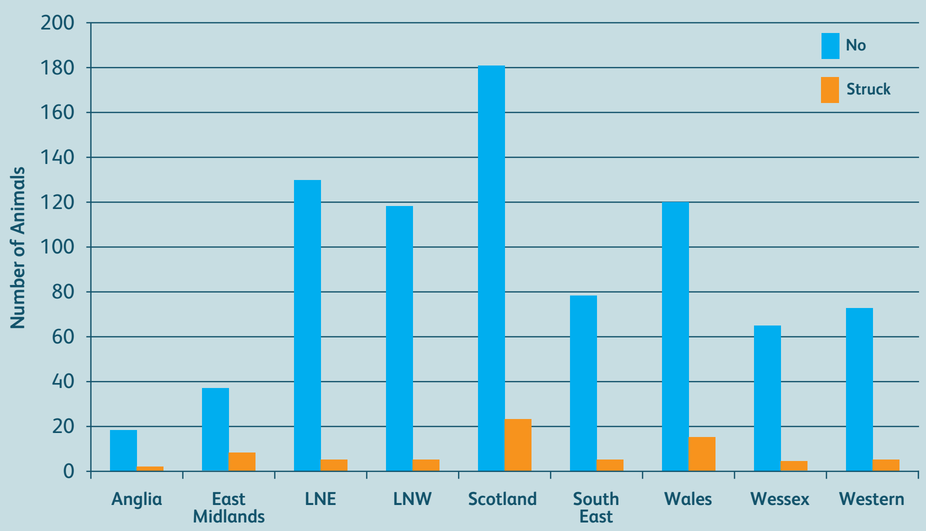


fig. 1

Analysis of causes

Priority problems

Specific priority problems

- We are alerted only at the point of when the asset fails or is about to fail.
- We are unable to demonstrate the configuration and condition of our asset.
- We react to recover the railway without investigation of the root cause.
- Some of our older, legacy, boundary designs are not adequate to prevent animal incursion.
- We lack robust systems to adequately identify and capture change in adjacent land use. This imports risk as we are then not controlling risk of incursion.

Related goals

- Asset management systems that are centred around appropriate levels of maintenance and renewal based on asset life cycle.
- An efficient system for capturing data and updating the asset register.
- Proactive and predictive measures that maintain the suitability of the asset for its location.

Benefits

- Improved performance as a result of a better-timed intervention.
- Increased asset life and improved whole life cost
- Efficiency savings by avoiding incidents.
- Improved performance as a result of better-timed intervention.

Specific research needs

We seek to operate with robust boundary measures able to meet their expected life cycle within the operating environment. We require design specifications fully tested to provide sufficient protection to withstand incursion by human and livestock. This will include benchmarking various materials used in fence construction and the methods of installation in terms of post and cladding, tension and durability.

We seek to understand how we can protect our assets from degradation. This will include protection methods and processes for steel and timber products. It will also include research into natural and introduced corrosive agents and reactions.

When boundaries fail, we seek portable systems that maintenance teams can use after incident and deploy efficiently .

We rely on a combination of inspection and information provided by others to update registers on land use. We want to develop to a stage where we always know what the land adjacent to the asset is used for, so the boundary can be adapted accordingly. We need to explore alternative methods that can provide consistent information regarding land use change.

We manage approximately 28,000km of boundary measure. We need to be confident that inspection covers all of the asset. Inspections are undertaken by field teams over terrain that is difficult to access safely. We seek safe inspection methods that can be completed by other methodologies, especially when access is interrupted.

We need assurance that any boundary repairs undertaken provide either the same or improved security, compared with the original installation. This includes assessing temporary measures that have been installed to repair the boundary where problems have occurred. Repair products must be effective without the need for regular maintenance and be quick, easy and cost-effective to carry out.

Safe and Effective Lineside Inspections

What is the situation?

The management of the lineside principally deals with:

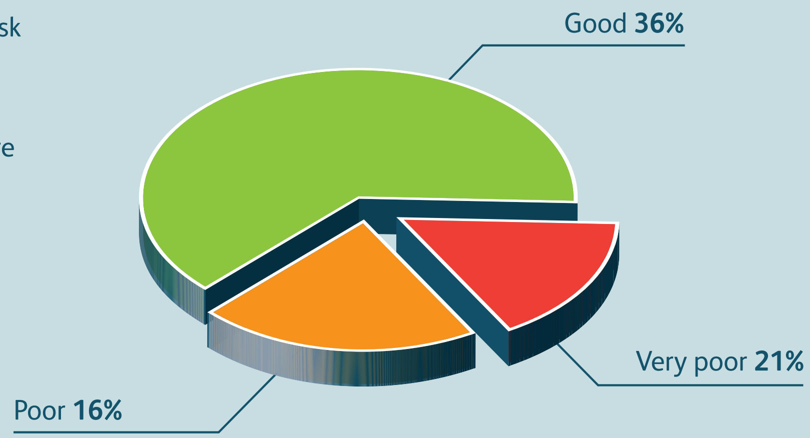
- Management of vegetation along the railway and within the boundary to reduce or avoid risk to the railway.
- Assuring a boundary is provided to satisfy a legal requirement and avoid trespass or incursion.

The current inspection regime for lineside assets is ineffective and inherently elements that are potentially unsafe. Workers are expected to negotiate slopes, barriers, unstable ground, hidden hazards and poor lighting to carry out visual and tactile elements. The topography of the lineside can even prevent access altogether for inspection. Technology could supplement or replace the need for accessing such areas.

The inspection regime does not take advantage of any technology to avoid or reduce reliance on human intervention.

Human factors also play a part. "Familiarity breeds contempt" and the inspectors can accept poor quality data and currently do not challenge the need to improve (the graph below illustrates a scenario, while of considerable concern, is not felt to be accurate). The manual, repetitive and basic nature of the task can lead to the inspection being undervalued.

The lack of full condition assessment, mean interventions are not always made prior to asset failure.



Priority problems

Specific priority problems

- Recording a full assessment of the asset condition and risk during inspection and survey.
- Placing the inspector in a potentially unsafe environment by having to carry out visual and tactile inspections in hazardous environments.

Related goals

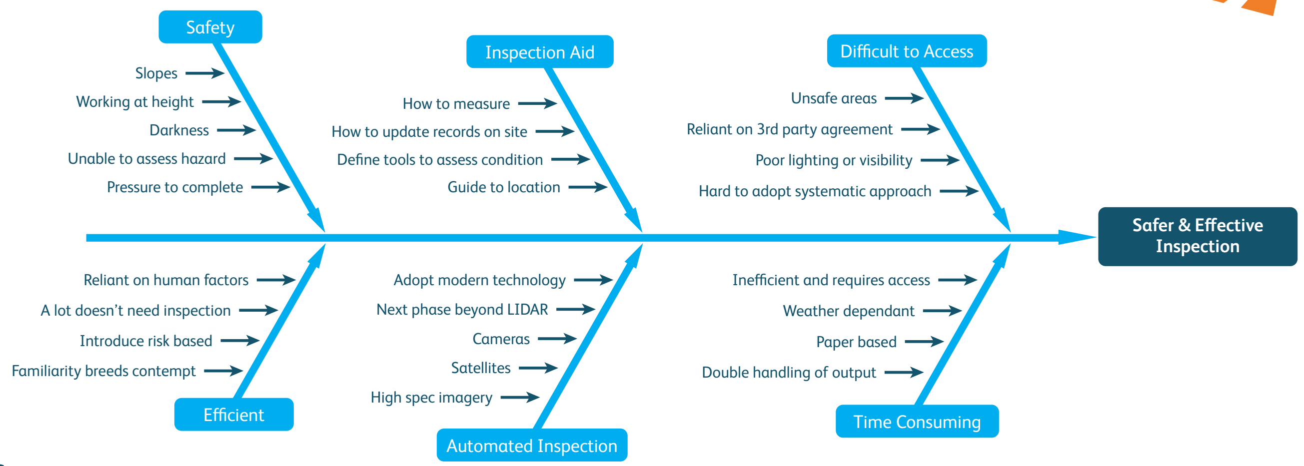
- Provide a better understanding of the preventative measures required at the appropriate frequency.
- Use technology to remove exposure and in turn satisfy the safety vision.

Benefits

- Significant reduction in asset failure and reactive maintenance.
- Reduction in financial penalty to the business from performance penalties.
- Reduction in safety risk to the business by providing an enhanced more reliable asset.
- Improved efficiency, better engagement, and improved staff safety.

NetworkRail

Analysis of causes



Scope

A core requirement of this challenge is to remove the risk from those carrying out the inspection. Future inspection methods should make use of remote techniques. We need to learn from the inspection regimes used on the same or similar assets. Enabling a thorough assessment that satisfactorily manages safety, financial, performance, environmental and reputational risk.

The extent of a visible asset is limited on a number of inspections as we have to prioritise safety where trying to access the asset and where there is limited time available, productivity. Being more intrusive is more effective and a necessity where tactile assessments are required for the boundary measure. The most challenging element will be if there is an effective alternative to the tactile assessment of boundary measures.

The means of recording output from inspections is inefficient and prone to error as it mainly relies on manual recording and transfers to our asset management system. There are electronic means available to transfer the output directly but these are not widely adopted. The perception is that they are more arduous and result in a loss of productivity. They need to be designed for entry by individuals at the "lower end" of IT literacy and need the scrutiny of experts to make them more user-friendly.

We have started to use Light Detection and Ranging (LiDAR) survey methods to assess the vegetation asset and its risk to the operational railway. It is believed that the potential and limitations of this relatively new method as an aide or replacement for inspection are unexplored. We require expertise to highlight the benefits of the current or new uses and recognise any weaknesses and limitations.

We are particularly in need of expertise to identify a better business change to maximise the use of the output at a level relevant to the business need. We should not limit ourselves to aeroplane, helicopter or drone as a means of capture and any method, with a suitably advanced level of technical readiness, should be considered as an alternative to help meet our challenge. This could include vehicle or satellite based capture and consider direct imagery or analysis with associated reconstruction. Within the business, we have a centrally managed Geographical Information System (GIS) which is branded as 'Geo-RINM'. The inclusion of items for lineside is currently limited to LiDAR output but the potential needs to be explored so that it aids inspection or it provides and immediate output.

To address these challenges it is expected that R&D actions will need to address the following aspects:

- What examples of alternative and evaluated inspection methods exist within different companies or industries that meet our challenge?
- What experience is there to evaluate different data sources and capture so that inspection regime is enhanced and more effective?
- What experience is there of using 'data, information, knowledge, wisdom' principles to enhance inspection methods in line with our lineside challenge?

Vegetation Management

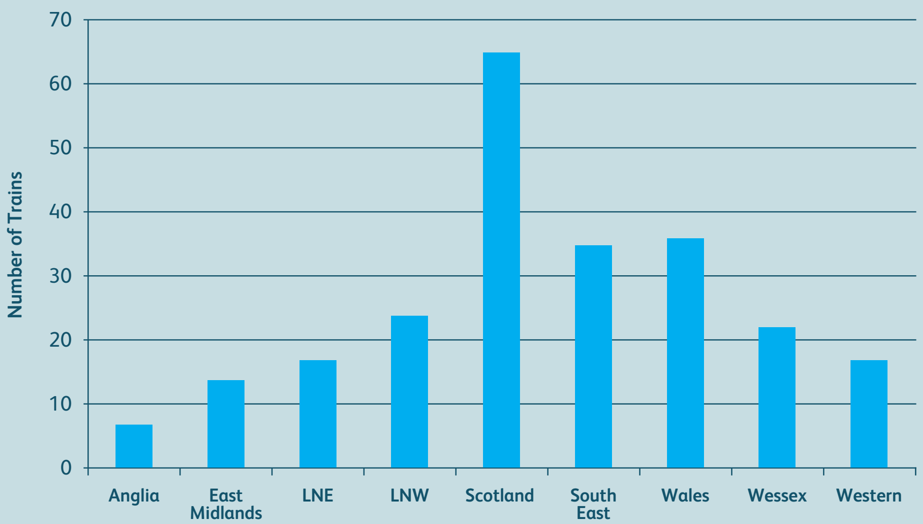
What is the situation?

Vegetation growth poses a risk to the safe operation of the railway by impeding sight lines, blocking access and damaging infrastructure. In certain locations, lineside trees have been left to grow to the size that, if they were to fail, would cause damage trains and service disruption.

We must not underestimate the impact that vegetation can have on third parties. We have a duty of care and environmental responsibility to observe.

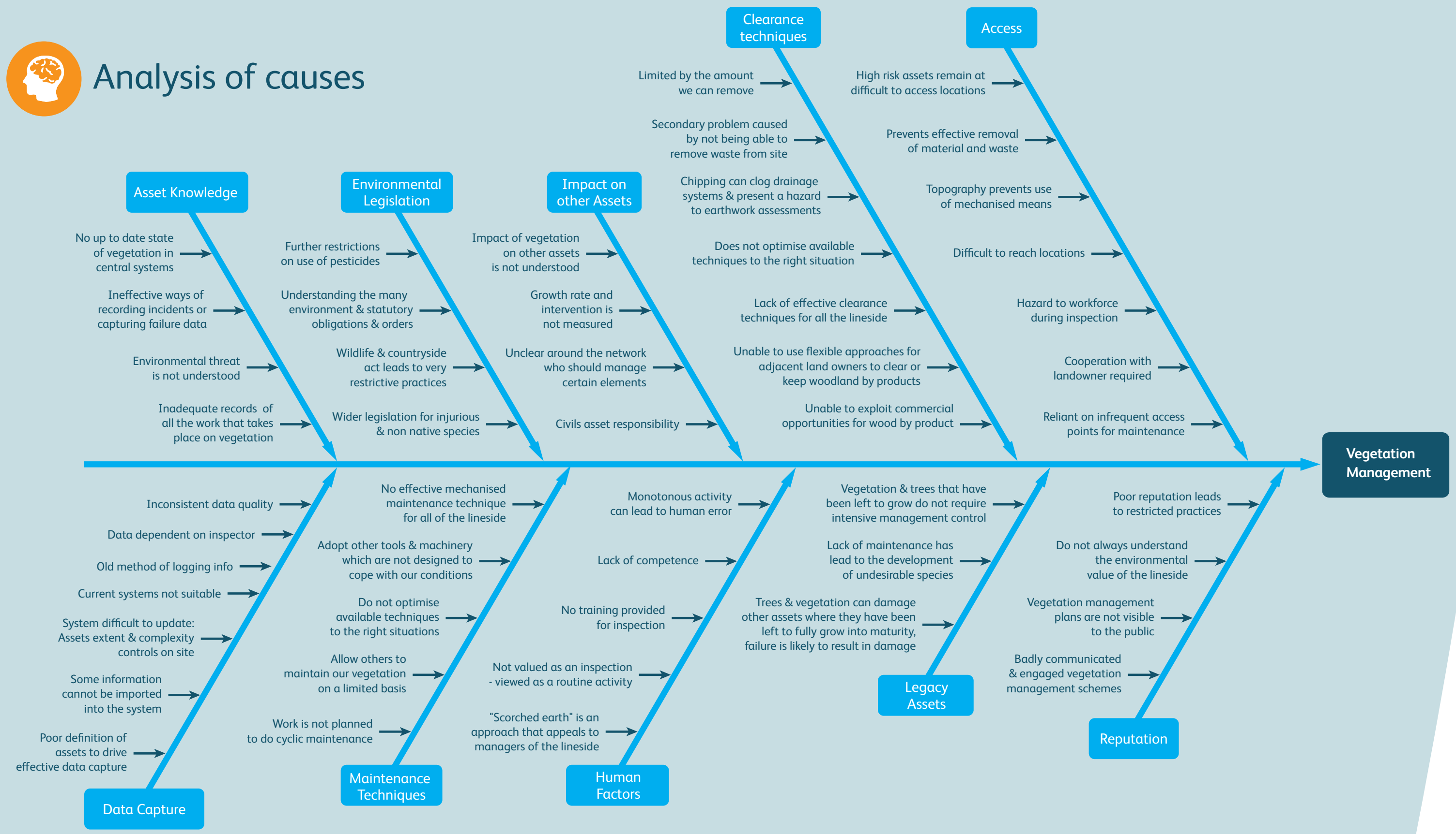
Vegetation management interventions employed to manage this risk, can be complex, potentially hazardous and must consider the impact on the wider environmental aspects.

Trees struck train



Vegetation encroaching tracks

Analysis of causes



Priority problems

Specific Priority Problems

- Current specification does not prevent tree failure risk.
- We are currently reactive, not proactive to compliant conditions.
- Our clearance and maintenance activity doesn't sufficiently prevent growth from disrupting the operational railway.
- Our maintenance options need to consider the impacts on the natural environment .
- Reactive responses, often in poor weather conditions' are potentially hazardous.

In addition, we need to understand:

- The social and environmental relationships when undertaking work.
- The effects of vegetation (good and bad) on other civil assets.
- The safety risk with regard to electrical induction.
- The risk of blocking or obscuring critical assets.
- The risk posed by leaf contamination (effects of Autumn regarding rail /train wheel interface).
- We do not fully assess the risk to the railway and our neighbours posed by lineside vegetation.

Related Goals

- Intervention zones that limit the disruption from vegetation growth.
- Effective clearance and maintenance regimes that prevent regrowth.
- Inventory that completes the knowledge of the asset in terms of flora and fauna.
- Management plans that set the strategic goals and time scales.
- Understanding of vegetation intervention in relation to growth rates at the appropriate frequency and techniques.
- Understand the parameters required that can affect the performance of the railway during autumn.

Benefits

- Our operations and assets are not disrupted by vegetation growth.
- We have the capability to clear and maintain the asset.
- We know our asset so that we can predict life cycles and apply the safest, most efficient, intervention method.
- We own the asset and commit to the performance requirements.
- We share our approach with our stakeholders with confidence.
- Asset failure reduction, safer services.
- Business cases supported for clearance operations that will improve performance.

Specific research needs

We seek to complete our vegetation management asset inventory so that it has the capacity to capture specific requirements with regard to risk to the railway. This will involve efficient means of capturing location and height of vegetation and specific requirements such as species type, age classification, condition and local and regional growth rates. This will also include means to capture areas that require special treatment either in controlling the spread of undesirable species or to encourage desirable conditions.

We strive for vegetation management plans that provide clear strategic vision. Setting out our short, medium and long-term commitments for clearance and our future maintenance activities, in line with the types of vegetation being managed and the environment in which it exists. Thereafter, we seek best means of communicating our plans to our stakeholders.

We continually seek to adopt alternative means of treatment that offer safer and efficient ways of working. Our railway operations and adjacent terrain provides a challenge to the traditional methods of vegetation management. Our intervention needs to tackle this but also undertaken at a time and at frequencies that has no detrimental impact on the natural environment.

We seek to research features that inform on asset degradation. This will consider how current and emerging pest and disease could affect the lineside in the future and what it means in terms of accelerating our management plans.

Enabling Transition to Predict and Prevent Maintenance Regimes

What is the situation?

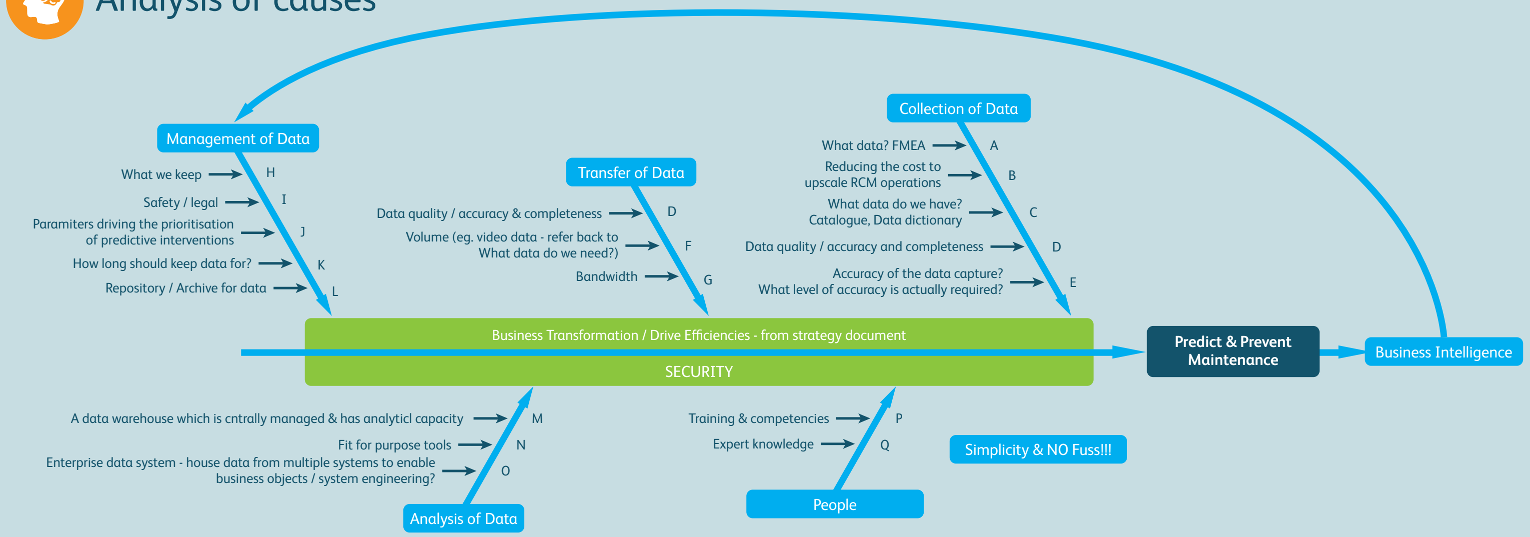
We have made significant progress in delivering efficient and effective maintenance, providing the foundation for our strategy:

- Improvements have been made understanding and monitoring the asset base resulting in the lowest number of service-affecting failures of all time.
- Aspects of our infrastructure monitoring capability are recognised as best in class. Broken rails have been below our control limit for 12 of the previous 13 periods.
- Excellent progress has been made with defining and implementing reliability centred maintenance regimes.

Despite these improvements, there are further opportunities:

- CP5 Maintenance expenditure has not reduced at the rate forecast at the start of the control period.
- Delay due to asset failure is increasing despite the number of failures falling.
- Track access required for maintenance does not align to train service specifications.
- Condition monitoring data is not yet utilised to generate predictive and preventative maintenance regimes.
- Potential reduction in renewals volumes in CP6 will require effective and high-quality maintenance task delivery to maintain the sustainability and performance of the asset base.
- The data currently held does not have the quality and granularity required to fully deploy predict and prevent maintenance.
- Maintenance regimes are not optimised based on risk and need to be effective at balancing spend against the impact of asset failure.

Analysis of causes



Priority Problems

Specific Priority Problems

- Advanced analytics are not utilised to understand asset condition and define timing and type of maintenance intervention.
- Data sources are not integrated and analysed to understand how the railway is performing as a system.
- There is no defined systematic approach to optimise maintenance regimes based on performance risk.
- Insufficient sensor capability has been deployed to either fixed or mobile infrastructure.

Related Goals

- Exploit existing data sources to enable improved decision making, optimise maintenance regimes and prevent asset failure.
- System based analysis (e.g. between track geometry and points RCM) will further improve predictive capability.
- Maintenance regimes are optimised to reflect the impact of failures in each location.
- Improved capability to predict and prevent asset failure and optimise maintenance regimes.

Benefits

- Reduced maintenance and renewals cost, improved train performance and safety.
- Enables trade-offs in maintenance spend to benefit train performance.

NetworkRail

Scope

The challenge is to explore where sensor technology and analytics can be combined with robust Failure Modes, Effects and Criticality Analysis (FMECA) to enable a prioritised transition to predictive and preventative maintenance.

Activities required to deliver this are:

- Deployment of technology to provide cost-effective data capture and transfer, utilising both fixed and mobile sensors.
- Software to support rapid deployment of demonstrators for technology, analysis and prognosis.
- Cost effective data management and analysis of monitoring systems fitted to service trains.
- Deployment of enhanced analytics on existing data sources to develop prognostic capability, including the development of health scores for each individual asset/junction/ELR.
- Development of a system, fully integrated with our fault and asset management systems, to enable data technicians to monitor asset health and prescribe maintenance regimes.

Specific research needs

To address these challenges it is expected that R&D actions will need to focus on the following aspects:

What remote condition-monitoring technologies are available for deployment to predict and prevent asset failure and/or replace existing manual maintenance regimes beyond solutions already embedded or in a trial in our Intelligent Infrastructure system? There is a requirement for:

- Level crossing monitoring – c. 1400 assets.
- Train borne monitoring of Signalling Equipment – initial pilot on NR monitoring fleet with potential for fitment to in-service trains.
- Train borne monitoring of S&C – it is anticipated up to six trains may be required.
- Ideas/prototypes/demonstrators/systems that are in use/development in other railways/industries.
- Overcoming recording speed constraints with current data collection technologies e.g. rail flaw, eddy current – there are currently five systems in use on a dedicated monitoring fleet.
- Transition to unmanned systems on our fleet of monitoring trains.

Provision of additional insight from existing data sources. Pilots for diagnosis of points condition and prediction of track circuit failures have been developed and will be tested in the near future but there are many other opportunities:

- Expand points condition diagnostics to predict asset failure.
- Expand track circuit predictions to diagnose failure modes.
- Develop prognostic capability for all assets fitted with condition monitoring.
- Development of algorithms to establish degradation rates of our linear assets, utilising the outputs to improve planning of maintenance intervention, in particular for on track machines.

Provision of additional insight through the integration of disparate data sources. Examples identified are:

- How can points condition monitoring and train-borne monitoring data be integrated to understand the effect of poor track conditions on the life and reliability of points operating equipment?
- What is the performance risk of overhead line heights and staggers position moving away from the original design whilst remaining compliant to existing standards?
- How can changes in track stiffness be used alongside age and condition data to predict and prevent broken rails?
- Analytics developed in other railways or industries that could be transferred to Network Rail.

Creation/configuration and integration of a system bringing together the analysis created by the above schemes. This will enable the systematic and regular reassessment and optimisation of maintenance regimes in line with current asset performance.

Creation of a systematic and robust risk assessment approach utilising cross-discipline FMECA. Enabling trade-offs between maintenance-spend and the impact of asset failure where condition monitoring is or isn't fitted.

Expected impact & benefits

- Optimised maintenance costs, which could be increased if this provides a greater reduction in renewals cost.
- Delays per incident are reduced through use of diagnostic capability.
- Increased workforce safety.
- Improved train performance.

Risk of Plant Strikes – Colliding with Plant, Infrastructure or People

What is the situation?

There are three scenarios we must consider:

- Plant strikes other plant.
- Plant strikes an individual.
- Plant strikes a piece of infrastructure or object.

The primary source of control when moving plant is people. This creates a significant risk of incidents caused by human error. There is a great reliance upon compliance and individual competence, which is not always robust.

One of the NR lifesaving rules is for the creation of exclusion zones to separate people from plant, whilst this is embedded into procedures and processes, it is difficult to control and enforce. There is also a cultural issue in this procedure that is difficult to eradicate.

Collisions are costly from both a time and financial aspect as they lead to possession overruns and abortive repair costs. Overrunning possessions impact on our ability to provide train paths for an efficient timetable. This impacts on the fare paying passenger and also damages our reputation with the TOC's/FOC's.

With the increased demands for network capacity, we need to find technological solutions that reduce or eliminate the risk of human error.

fig. 1

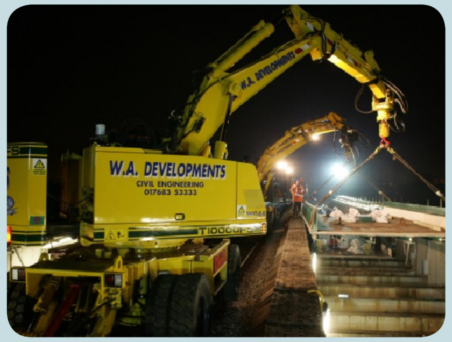


fig. 2

Priority problems

Specific priority problems

- People encroaching within machine exclusion zones.
- Reliance on machine operator to be able to react potential risks.
- Uncertainty surrounding limits of electrical isolations.
- Operator distractions.

Related goals

- To reduce likelihood of plant to people collisions.
- To provide automatic detection and control of unsafe machine movements.
- To provide means for automatic detection of Live OLE.
- Remove operator from cab and incorporate remote control into machine design.

Benefits

- Reduction in accident rates and consequential loss.
- Reduction in number of collisions between plant and infrastructure.
- Reduction in risk of electric shock and machine damage.
- Operator in close proximity to point of operation providing greater visibility of machine and load.

Analysis of causes

Specific research needs

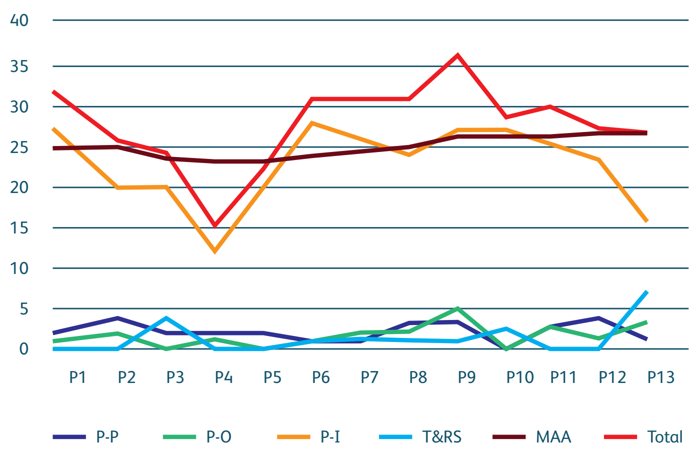
People encroaching within machine exclusion zones

Need a bolt on system that can be fitted to any item of plant to automatically alert the machine operator and individual that is encroaching simultaneously. The system shall be adjustable to meet the required exclusion zone of a particular item of plant and incorporate technology that provides individual members of workforce an immediate notification of encroachment without the need for the operator to monitor the exclusion zone. The system shall be linked to a web-based application that provides real-time transfer of information that enables data to be captured and individual performance to be monitored so that repeat offenders can be easily identified. Need to find way to completely remove collisions between plant and people.

Reliance on machine operator

Need to supplement reliable height limiters with additional means to detect the proximity of machine to infrastructure to automatically stop machine movements if encroaching too close to OLE or other structures such as station platforms. Need to eliminate collisions between plant and infrastructure.

2016 Period by Period collision data from Plant & T&RS Period Performance Report:



Uncertainty surrounding limits of electrical isolations

Products currently developed do not have proven reliability, nor do they have the ability to screen out signals from adjacent live roads. We Need to be able to accurately detect the presence of Live OLE on the rails on which the machine is mounted to prevent machines moving into non-isolated electrical sections with basket raised.

Operator distractions

It is sometimes difficult for operators to clearly see the interaction between the machine and load at the end of the machine boom due to obstructed vision or other distractions. Need to develop remote control systems to remove operator from machine cab and put the operator at the point of operation to clearly manage risk. The system is required to be tactile to provide the operator with the same level of control that he would be afforded in the machine cab whilst giving him full visibility of critical safety functions such as the Rated Capacity Indicator system status.

Understanding Plant Better and Improving Fitness for Purpose

What is the situation?

As the title of this challenge implies the two interlinked issues that need resolving are:

1.

Understanding plant better

Plant Safety hazards within each of the main machine type categories are mostly generic. New hazards tend to be driven by changes in task and operator competence rather than the railway environment (which is known, with drastic changes rare). The industry would benefit from the publication of these generic hazards and, where known, task and operator competence dependent ones. This would feed into current industry migration towards Common Safety Methods Risk Assessment.

STE, M&EE, Plant and T&RS have the accountability for making sure a number of services and activities are undertaken to ensure plant safety where we have an engineering responsibility, a big picture holistic model is required to demonstrate effective management of this responsibility.

The currently used tools are:

- Business Critical Rules Bow Ties.
- Enterprise Risk Matrix.

2.

Improving fitness for purpose

The continuous adaptation of civil-based machinery for rail use always results in reduced production capability per machine and an increase in operational controls, which in-turn, drives an increase in the number of supervisor and controller personnel.

Service and Performance are to be assured in order to meet business objectives. Current isolate tool is the Road Rail Vehicle Performance System (RRVPS) managed by Infrastructure Projects.

Determining our Rail Infrastructure business needs by matching plant capability to maintenance, renewals and upgrade project tasks needs to be brought into the 21st Century.

This would in turn drive:

- Choosing the best machine for the job (more holistic planning mentality).
- Better planning that's easier and, as a result, cheaper.
- Earlier booking(cheaper because less late booking).
- Understanding plant shortages (reduce our internal functions being played against each other, further driving up costs).

Priority problems

Specific priority problems

- Planning (B).
- Safety Risk Model (C).
- Plant Strategy (F).
- Functional Definition (E).
- Supply Chain (D).
- Design for Reliability (A).

Related goals

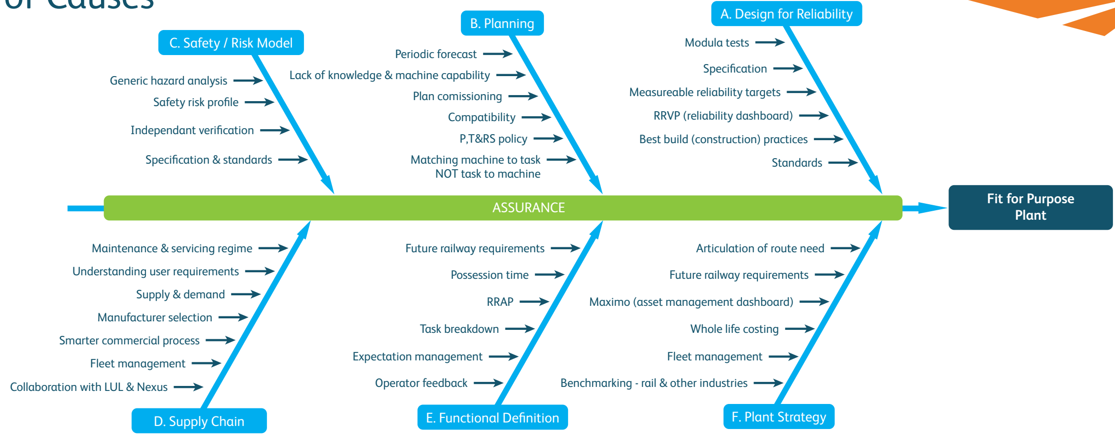
- Improve planning and plant selection.
- To improve the visibility of compliance to legislation.
- Route-driven demand for plant.
- Matching current and future business functional needs to plant capability.
- Developing mature supply chain that is aligned to NR business safety and performance needs.
- Upstream management of performance.

Benefits

- Avoid Plant incidents due to plant selection mismatch.
- Avoid Plant related Safety Improvement Notices.
- Route assessment of current plant usage and management capability and alignment to performance targets leading to the articulation of current and future plant need.
- Database linking business functional needs to plant capability.
- Single-minded leadership of supply chain.
- Feedback loop and continuous improvement of plant performance within the design.

Analysis of Causes

NetworkRail



Scope

A Plant Safety Risk and Reliability Model (PSR&RM) would help lead and drive the railway industry plant community to achieve continuous improvement in the health and safety and performance. To facilitate this, an understanding of the overall risk level, risk profile, and the demand of railway plant is essential. The functions of the PSRM would be:

- Risk Profile Tool.
- Risk Management Tool.
- Reliability and Performance Tool.
- Functional Requirements Tool.
- Plant Strategy Tool.

The PSR&RM could be a quantitative or qualitative representation of potential safety and reliability incidents resulting from operation and maintenance. Comprising of individual models each representing the plant families, underpinning upstream and downstream assurance activities.

Where possible PSR&RM would be populated using the rail industry's related incident data. The PSRM would also include predictions of the risk contribution from low frequency and potentially high-consequence safety and reliability incidents.Where data is scarce, the model will be populated by expert judgement from technical specialists and plant managers.

Model requirements

- Sophisticated modular model and management system, capable of enabling a record of business as usual activities. For example the effect of a standards update or the impacts of increased assurance activities on control measures.
- Must be Common Safety Methods-Risk Assessments and Evaluation (CSM-RA) compatible.
- Must be compatible with existing NR functional requirement capture systems such as DOORs.
- Cyber security.
- Smart search and category algorithm, enabling easy rearrangement, navigation and grouping of plant types, safety measures and reliability parameters.

Expected impact & benefits

- **PSR&RM Risk Profile Tool**
  (A risk profile tool would contain risk information and risk profiles derived from the PSRM. It may include tables of frequency and consequence data from the PSRM so users can improve their risk understanding and management).
- **PSR&RM Risk Management Tool**
  (A risk management tool for industry stakeholders, quantifying the significant causes and consequences associated with each identified hazardous event. This would enable users to identify key areas of risk associated with their operations and to prioritise their investment in safety, using a risk-based approach.
- **PSR&RM Reliability and Performance Tool**
  (A reliability and performance tool to define reliability targets and link reliability requirements to performance).
- **PSR&RM Functional Requirements Tool**
  (A Functional Requirements tool holding all business activities requiring Plant solution. A database for linking business requirements to plant capability).
- **PSR&RM Plant Strategy Tool**
  (Route-driven and centrally authorised company strategy spelling out business plant needs).

Automating Inspection and Maintenance Activities to Remove Workforce from High-Risk Areas and Improved Data Capture

What is the situation?

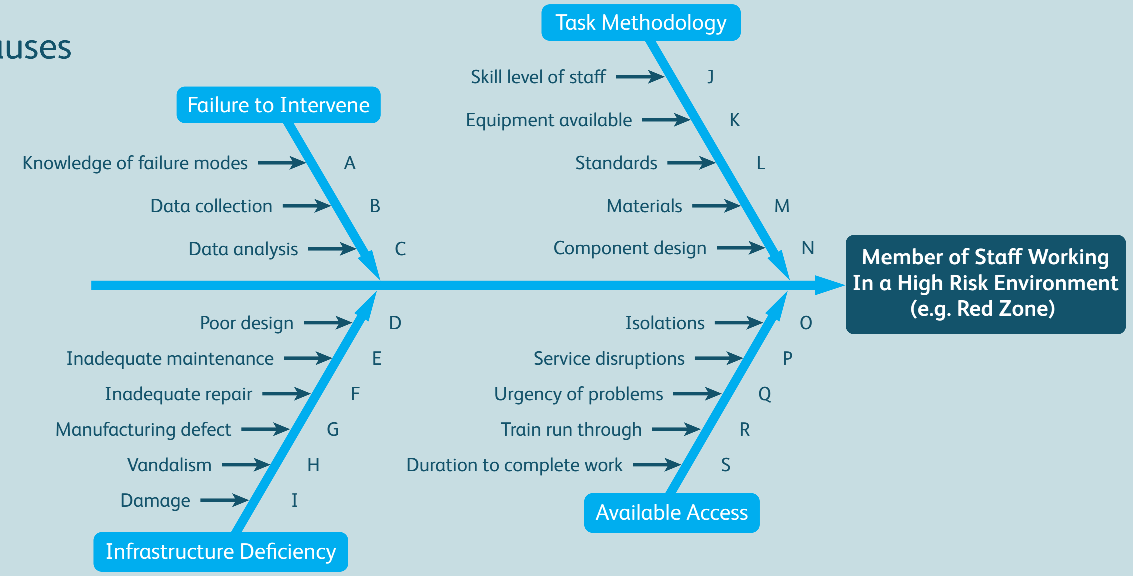
Robotics, Automation and Artificial Intelligence (RAAI) offers a potential step change in the way we manage asset data, undertake infrastructure inspection and maintenance activities on the UK railway network. This innovation will help us to deliver key business objectives of safety, performance, customer experience, capacity, cost efficiency and sustainability.

The introduction of the Digital Railway and the deployment of ERTMS will lead to an increase in capacity of the network. As we increase capacity and run more train services, the opportunity to undertake maintenance operations will reduce and degradation rates will increase.

We also need to accurately understand the condition of the assets so we can plan and perform timely maintenance activities. Autonomous systems will monitor the network, providing Artificial Intelligent Systems the data to analyse and develop trends of asset-risk. This will enable decision support tools to schedule the most effective inspection and maintenance programs with minimal disruption.

More trains will equate to more wear on the infrastructure. This will lead to an increase in inspection and repair requirements. We need to be more productive with possession time. It is expected Robotics and Automation could be one answer in enabling more productivity.

Analysis of causes



Priority problems

Specific priority problems

- Carrying out inspections in hazardous environments puts staff at risk. Therein a need to investigate means of doing this autonomously or remotely to reduce the risk.
- Demonstrating improved quality of inspection data capture (reproducibility and repeatability).
- Create an economical solution, where all devices are modular and use common communication protocols.
- Providing proof-of-concept within a system engineering environment.
- Logically planning the progression along the degree of automation.

Related goals

- Creating an overarching systems architecture to operate all remotely controlled (unmanned) systems.
- Concept demonstrator for:
  - railhead repairs and
  - brick-lined tunnel inspections.
- Identifying and replacing, through technological development, further high-risk activities currently performed by some front-line staff to go through the same process.

NetworkRail

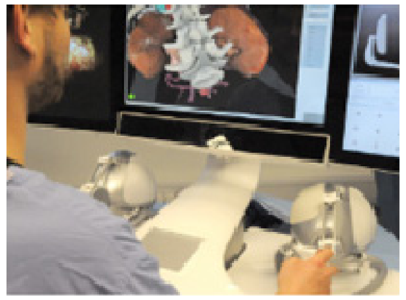
Scope

There are significant challenges facing the railway, including a need to reduce disruption to services.

The requirements are to:

- Improve workforce safety: be more productive using automation and increase the reliability of the infrastructure, thus increasing the capacity of the infrastructure.
- Improve workforce safety: reduce the need to access the infrastructure, develop technologies to enable activities to be remotely controlled from safe areas and mechanise and automate processes to remove manual tasks.
- Increase infrastructure reliability: automating inspection activities would improve the precision and accuracy of the data collection, introducing data analytics, removing human bias from these activities, improving repeatability and reproducibility. This will improve information about asset condition, inform inspection and repair schedules based on asset risk.



Both the Rail Technical Strategy (RTS) and Network RTS identified that autonomous robotic systems could be a potential step towards a resolution.

Demonstrator Statistics: Quality issues (e.g. Level of Rework); Number of staff working red zone; Level of injury due to manual handling/HAV.


RAS 2020
Robotics and Autonomous Systems
A national strategy to capture value in a cross-sector UK RAS innovation pipeline through co-ordinated development of assets, challenges, clusters and skills / July 2014



Expected impact & benefits

We see this technology being used in two main scenarios:

- Development of a distributed sensor network enabling data to be provided to modelling, analytical and decision tools to support systems. With the aim of reduced cost and maximised network availability for routine inspection and maintenance interventions.
- Development of modular robotics to automate maintenance and inspection activities. This will reduce the requirement for infrastructure access improving worker safety, reducing cost and maximising network availability for routine inspection and maintenance interventions.

Reliable and Resilient Crossings

What is the situation?

Crossing failures can create major safety risks and generate huge annual costs. Repairing failures exposes rail staff to operational environments or risks are transferred to operations and managed with caution speeds and driver observations.

A total of 216 reported crossing faults occurred between 2013/14 and 2015/16 (3 years), totalling £12,336,998 in performance related (schedule8) costs alone. Of these, 80 % (£9,824,579) were associated with cracked cast crossings (054 failures).

Over a seven month period (April 2016 to November 2016) a total of 560 crossings were ordered, of which more than 75 % were related to cracks identified in crossings. The estimated annual costs for cast crossing replacements and their attributed delay penalties equates to over £24,000,000 per year.

Analysis of causes

Priority problems

Specific priority problems

- Poor resilience of cast Manganese crossings due to material susceptibility to fatigue cracking.
- Inability to efficiently monitor critical failure modes of existing crossings.
- Wheel to crossing interaction results in significant dynamic contact forces that drive accelerated whole asset degradation.

Related goals

- Reduce whole life cycle cost of cast crossings.
- Increase network capacity by improving RAMS performance of crossings.
- Improve remote condition monitoring of existing crossings.
- Improve remaining life predictions for risk-based maintenance of crossings.
- Reduction in Schedule 8 payments from cast crossing failures.
- Reduction in emergency crossing placements due to unforeseen failures.

Specific research needs

To address these challenges it is expected that R&D actions will need to address the following aspects:

- How can alternative materials or coatings be utilised to enhance the performance of crossings? Improvements should prolong life, reduce whole-life cost and reliance on maintenance. Weld repair processes should be considered for any alternatives.
- Optimise crossing (wing and nose) profiles using a combination of analytical and practical techniques. Consideration of manufacturing methods should be given.
- How can improved inspection methods (both automated and manual) help predictive maintenance whilst furthering our understanding of precursors to wear/damage?
- A full system model of crossings, including ironwork, bearers and under-bearer support conditions will assist predictions for crossing failure.
- What improvements can be made to monitoring and maintenance of crossings including RCM? How can we use existing data to improve understanding of failures?
- Enhanced vehicle dynamics modelling will help drive improvements to crossing design and understanding of failure modes.

Reliable and Resilient Switches

What is the situation?

fig. 1

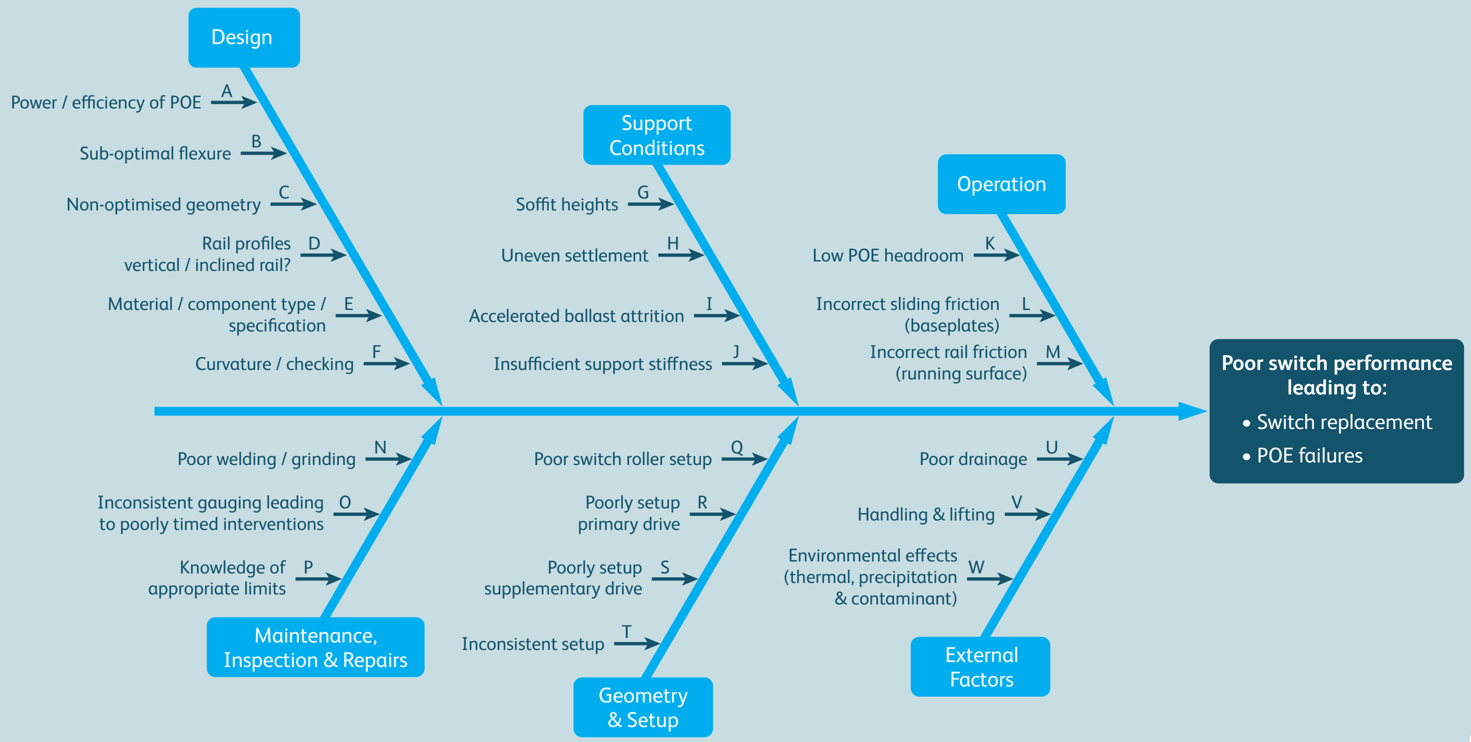
Switch failures can create major safety risks and generate huge annual costs.

Switch and Points Operating Equipment (POE) represent one of the most safety critical aspects of our infrastructure. Failures often expose workers to hazardous live railway environments or risks managed with safeguards such as caution speeds and driver observations.

Switch failures are a contributor to poor network performance. Switches and POE that wear rapidly or enter a deteriorated state must be maintained and replaced more frequently. This increases the whole life cost of the asset, making the challenge of improving and increasing infrastructure capacity more complicated.

Track access to carry out essential works is a premium commodity and the need for switches and POE to operate safely and reliably with less hands-on maintenance is greater than ever before.

Analysis of causes



Priority problems

Specific priority problems	Related goals	Benefits
• Unreliable switches and POE systems.	• Build in resiliance to temperature and environmental variations.	• Consistent performance of assets, year round.
• Poor control of alignment/ geometry/maladjustment.	• Self-adjusting S&C. Automated inspection.	• Performance, safety and cost reduction (fewer boots on ballast).
• Lack of access for maintenance with increased capacity (i.e. Digital railway).	• Link to self-adjusting. Higher MTBSAF.	• Realisation of increased capacity.
• Information management for S&C - myriad of analysis/data sytems.	• Align with a joined up asset management approach.	• Greater knowledge of asset condition and life leading to better maintenance/renewals plans.
• Lack of resiliance in modular S&C.	• Develop alternative bearer tie systems.	• More (and more reliable) modular S&C, driving down cost of renewals
• Inadequate training and competency.	• Improve access to training resource & asset knowledge. Information Hub.	• Greater trackside.
• Complexity & human factors.	• Simpler design, less hands-on maintenance/installation.	• Reduces strain on competence development - human errors are difficult to predict.

To address these challenges it is expected that R&D actions will need to address the following aspects:

- How can alternative materials or coatings be utilised to enhance the performance of switches? Improvements will prolong life, reduce whole-life cost and reliance on maintenance. Weld repair processes should be considered for any alternatives.
- Optimise switch-profile and geometry to minimise wear/damage whilst reducing derailment risk. Consideration of manufacturing methods should be given.
- How can improved inspection methods, both automated and manual, help predictive maintenance whilst furthering our understanding of precursors to switch wear/damage?
- Improved understanding of the principles behind UIC716R and how it can be applied to UK switch designs.
- A fundamental understanding of switch design, flexure and drive forces is key to optimising point operating equipment and supplementary drives.
- What improvements to wheel/rail and slide plate friction management can be made? Considerations should be given to new plate materials, coatings, lubricants and roller technologies.
- How can alternative and innovative actuation, locking and detection systems improve reliability, reduce whole life cost and result in a reduction in maintenance?
- How can enhancements to existing actuation, locking and detection technologies improve reliability, reduce whole life cost and result in reductions in maintenance?
- What improvements can be made to monitoring and maintenance of switches including Remote Condition Monitoring (RCM)? How can we use existing data to improve understanding of failures?

Structures health monitoring and prognosis

What is the situation?

Network Rail's structures asset portfolio is substantial; the budget for management and renewal of structure assets within Control Period 5 (2014-2019) is circa £2bn. There are few if any single organisations in the world that are responsible for the management of a portfolio of this size and age. This includes approximately:

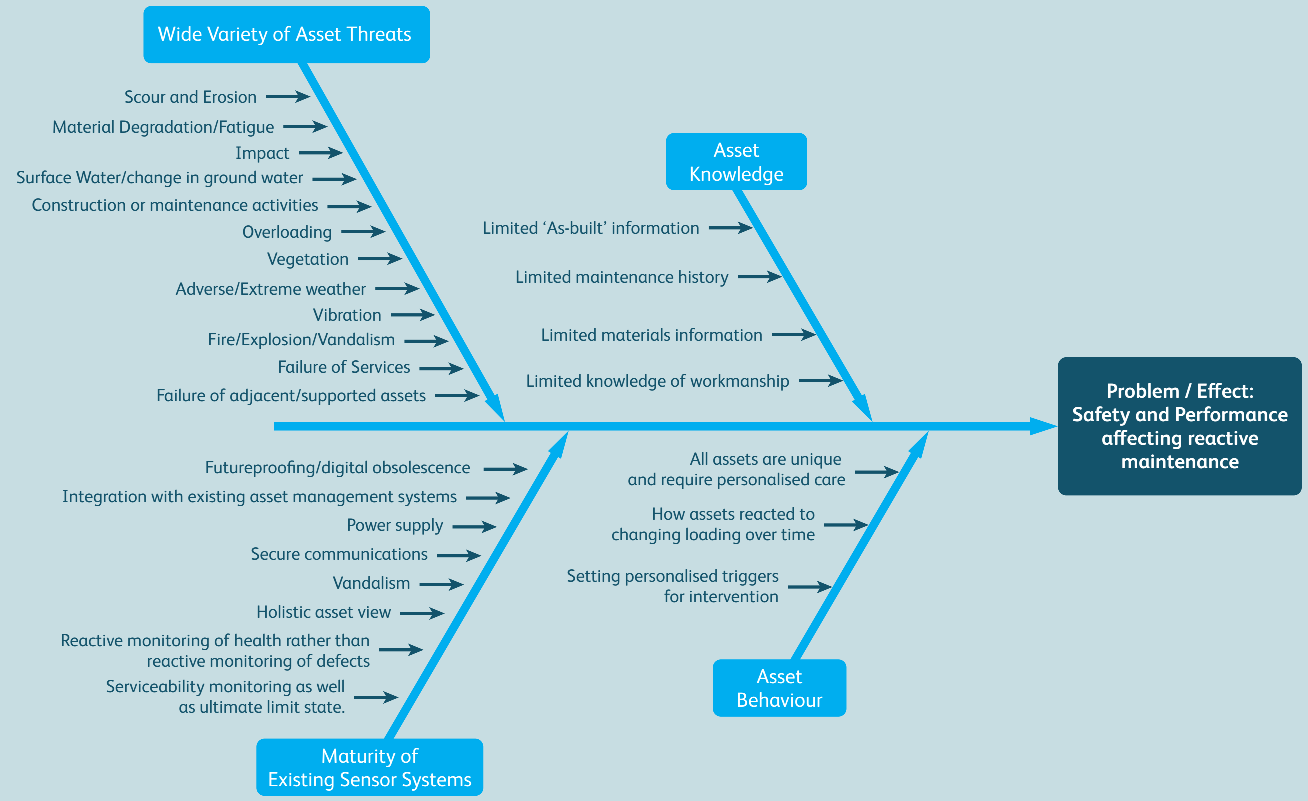
- 28,000 bridges range from modest rural utility bridges to complex multi spanned structures such as the Forth Rail Bridge
- 22,000 retaining walls, many of these significant structures in their own right 15 metres or more high
- 1400 footbridges
- 22,000 culverts
- 200 miles of coastal defences
- Over 100,000 ancillary structures, including masts, lighting columns and signal posts.

The majority of these assets were built over a hundred years ago before the advent of modern design codes. Their longevity, construction form, size and failure mechanisms have led to a perception of robustness that in many cases may not exist. Early structures were typically constructed from masonry, cast iron or wrought iron. Early steel was introduced at the turn of the twentieth century. For these older assets there are no records linking their performance with the loading that they carried or were designed for. Neither is there reliable information on original construction form, maintenance history, materials and workmanship from that era, so we are faced with a great many uncertainties.

Condition inspections of structures assets rely heavily on data collected by examiners in the field. Many of the data sets collected are subjective creating incomparable, and sometimes unreliable, data sets. This limits the extent to which asset condition and potential failure can be accurately determined. The recording of condition data could also be seen only as recording a proxy for loss in structural capability.

Routine capability assessment of structures is normally limited to bridge assets and undertaken on an 18 year rolling cycle. Assessments are traditionally complex, expensive and time consuming.

Analysis of causes



Priority problems

Specific priority problems

- Better understanding of asset threats – how can these be predicted? What are measureable precursors?
- How do we determine the size, material and history of elements not currently visible?
- How do we better understand individual asset behaviour?
- Development of sensor technology with a lifespan and maintenance requirement congruent with the assets they are monitoring.

Related goals

- Greater understanding of asset portfolio allowing engineers to make better and more timely decisions
- Improved reliability of data
- Increased asset availability

Scope

The scope of the challenge is to explore how a holistic system for the overall health monitoring and prognosis of structures assets can be developed.

The scope covers new and novel methods for structural assessment, data collection, analysis and intervention.

Specific research needs

To address this challenge it is expected that research and development activities will need to address the following aspects:

- What remote structural health checks are required to individual assets that are to be supported by a holistic remote monitoring system?
- How can serviceability of a structure be remotely monitored?
- How can structural capability be calculated instantly on the receipt of new data from the field?
- How can structure condition data be remotely captured efficiently, reliably and repeatedly?

Expected impacts and benefits

- Improved asset knowledge supporting greater asset availability to customers
- Reduced volume of performance affecting reactive maintenance
- Lower whole life cost through more effective and efficient maintenance
- Improved workforce safety through reduced requirements for site visits.

Improved Application of Friction Management to Prevent Defects, Derailments & Extend Rail Life

What is the situation?

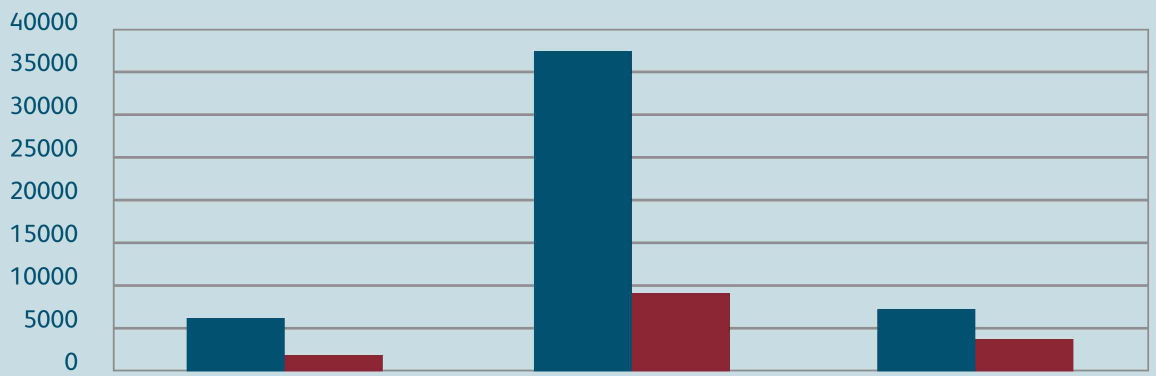
The continuous contact between the wheel and the rail surface is less than one square centimetre (around that of a 10 pence coin) and the infrequent flange contact surface area less than that of a one pence coin. Managing rail friction enables the management of these contact stresses to prevent flange climb, rail/wheel slip and rail wear.

In short radius curves or locations where there are significant centrifugal forces, flange contact generates significant lateral stress, flange wear and derailment risk (particularly at low speeds on tight radius curves). The impact of these forces is reduced by effective friction management.

Studies suggest that a rail on a curve that is lubricated has an EGMT life of 4+ times that of an unlubricated rail. Reducing the lateral stress also reduces the carbon footprint (CO_2 emissions) of locomotives.

Friction management is an evolving field. Research, development and application of friction management techniques and remote condition monitoring offer an opportunity to mitigate the risks arising from high friction more efficiently, effectively and safely.

National Lubricator Volumes



	Total Number of Trackside Units	Individual Maintenance Visits (8 Weekly Freq)	Showing M&H 80% Elec 60% Reduction
Mechanical & Hydraulic Units	6158	36948	7390
Electic Units	6158	36948	7390

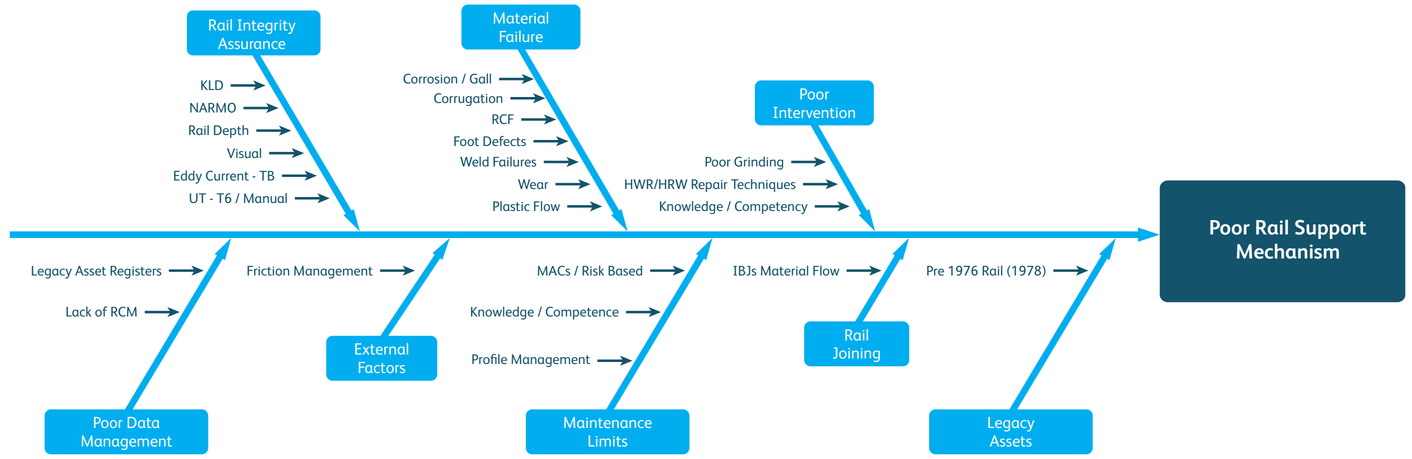
Efficiencies from implementation of the challenge statement would drive a saving of maintenance costs (no information to predict the measure) but would benefit everyone home safe every day by a reduction of 35000 trackside visits per year required nationally. There would also be benefits to the TOC's and FOC's in wheel wear and fuel reductions by reducing forces.

Scope

The scope of the challenge is to explore how a more effective way of friction management can be introduced into the UK network that requires engagement and benefits for all the key stakeholders.

NetworkRail

Analysis of causes



Priority problems

Specific priority problems

- Failing to manage the friction between the wheel and the rail reduces wheel and rail life and increases the risk of derailment due to flange climb.

Related goal

- To develop technology that enables reliable management of friction between the rail and the wheel.

Benefit

- Reduce asset whole life cost.
- Reduce the track asset risk profile.
- Reduce the track worker risk profile.

Specific research needs

To address these challenges it is expected that R&D actions will need to address the following aspects:

- Analyse the costs and benefits of improved friction management for each of the key stakeholders incuding NR, DfT, RSSB, vehicle manufacturers and FOCS/TOCS, encompass new build and existing rolling stock.
- Explore the benefits and limitations of TOR will enable us to manage the impact of steering forces on the rail reducing damage and extending rail life.
- Conduct a market review to identify existing or products under development that are cost effctive, environmentally friendly and deliver equivalent or enhanced performance.
- Research and development of existing non rail products and technology to reduce wheel/rail friction and consequential rail wear by the application of surface coatings to the rail head.
- Research the capability to measure the thickness of lubricant applied, the degradation of the lubricant in situ and the rail surface coverage will enable us to monitor the performance of friction modification systems and ensure they are efficient, effective and have minimal environmental impact.

Rail Head Squats

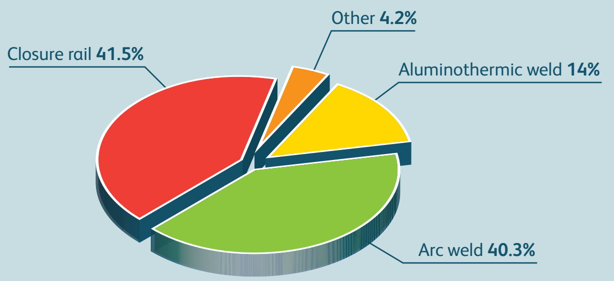
What is the situation?

A rail head squat is a surface defect caused by metal fatigue. Rail head squats cause a large volume of corrective maintenance which costs us millions of pounds every year. As squats grow they can result in speed restrictions being imposed due to the risk of rail breaks. These attract penalty charges due to the disruption to customers.

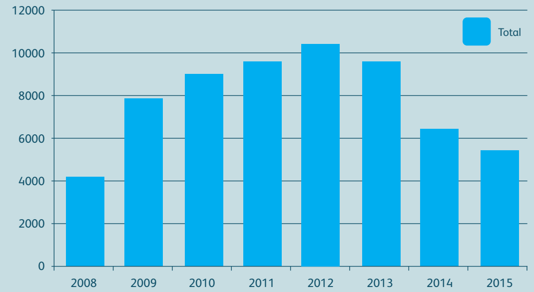
Information gathered from measurement trains detects thousands of new rail head squats every year. The increased number of squats isn't well understood.

Given the consequence of unrepaired squats deteriorating into rail breaks, there is a need to understand the causes of squat defects. We can then work to minimise or eliminate the causes, reducing their cost implications.

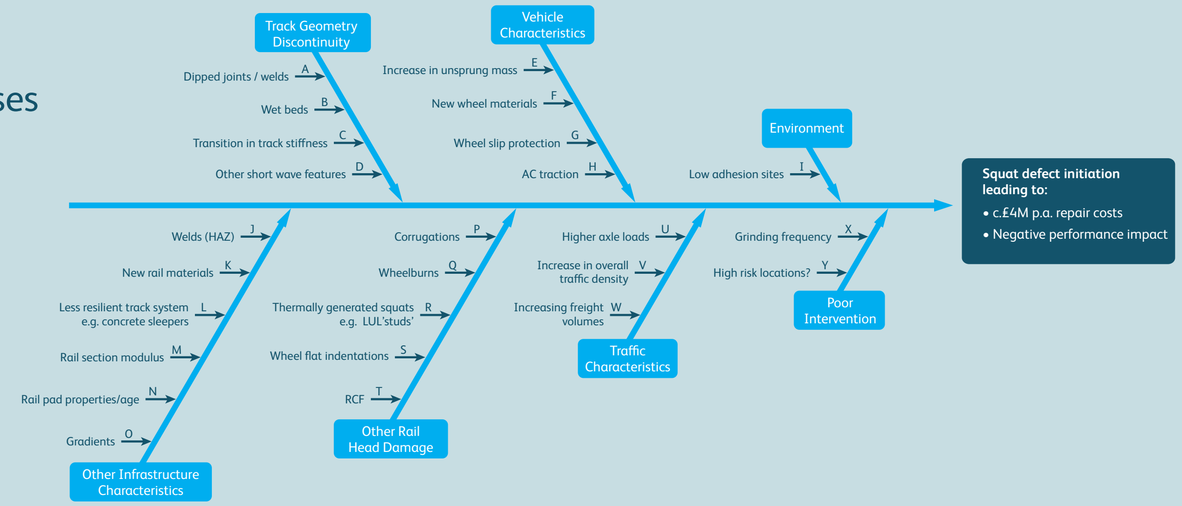
Squat repair method



Number of new squats per year (plain line)



Analysis of causes



Priority problems

Specific priority problems

- Lack of understanding of root causes of squats.

Related goals

- Identify track sections with the highest-risk of squats developing.
- Develop preventative maintenance that addresses the root causes of squat defect initiation in high-risk locations.
- Develop more effective and efficient corrective maintenance (minimum actions for grinding, weld repair).
- 75 % reduction in serious rail defects (reportable to ORR) due to squats by the end of CP6 (2015/16 baseline).
- 50 % reduction in the number of new squats detected per year by the end of CP6 (2015/16 baseline).

Scope

A lack of understanding of the root causes of squat defects and where they are likely to occur means we continue to suffer from rail breaks and serious rail defects. This results in speed restrictions on the network and the risk of derailment. Squats constitute the largest proportion of rail defects on the network and there is a need to reduce this by 50 % (based on 2015/16 levels)by the end of CP6.

A number of systems available, such as LADS (Linear Asset Decision Support) provide a visual representation of rail defects associated with geometry faults and other track features. However, there are gaps in this data that inhibit alignment at low adhesion sites. LADS also needs Intelligent algorithms developing to help detect rates of change and provide predictive information.

Modelling on vehicle dynamics to assess vertical rail damage, will help improve our understanding of the principal factors contributing to the initiation and development of squats on the gauge corner and running surface of rails and on curved and tangent track.

Specific research needs

To address these challenges further research and development will need to consider the following factors:

- Can we link operational and external (train) parameters into track condition data to gain a better understanding of rail squat propagation?
- Do the current inspection frequencies provide sufficient information to measure deterioration more accurately. Taking account of traffic volumes and wheel loading variations from different vehicles?
- Do we need to develop a better understanding of how rail head contamination and lubrication can lead to squats developing?
- Are there specific features in the trackform that can give rise to squats and do we understand the factors that cause these defects to arise?
- Can we explore the feasibility and benefits of installing rail head ultrasonic measurement devices on in-service trains, providing a more detailed picture of the propagation of rail head squats?

Expected impact & benefits

- R&D initiatives will identify the root causes of rail head squats and help to provide greater visibility of the features in the trackform that can result in squats.
- Research should help identify track sections at greatest risk of squat defects and help maintenance engineers develop maintenance strategies that will minimise the growth of squats.

This will support the development and implementation of efficient and effective corrective maintenance techniques. Delivering a 75 % reduction in the number of serious rail defects related to squats.

Rail Stress Management

What is the situation?

The management of rail stress to prevent track buckles is one of the highest track risks on the network.

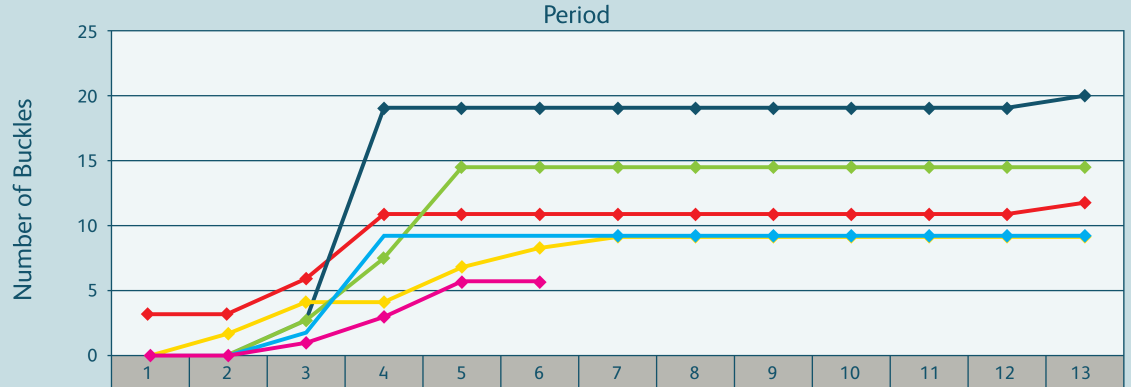
The causes of buckles with jointed track are: not adequately rail adjusted, bolts over tightened, lack of ballast and others. While continually welded rail (CWR) and switches and crossings suffer from a lack of stress and ballast.

Despite understanding the controls necessary to maintain and manage a safe and reliable railway, we continue to suffer from track buckles each year.

Systems for capturing and informing of rail stress aren't integrated and are out of date. These deficiencies can lead to train delays and impact on customers.

Additionally, the ability to measure rail stress non-destructively, is still difficult. The only approved method for measuring rail stress, the VERSE testing equipment, has several limitations.

Track buckles since 2011



Period	1	2	3	4	5	6	7	8	9	10	11	12	13
11-12	3	3	6	11	11	11	11	11	11	11	11	11	12
12-13	0	2	4	4	7	8	9	9	9	9	9	9	9
13-14	0	0	3	19	19	19	19	19	19	19	19	19	20
14-15	0	0	3	7	14	14	14	14	14	14	14	14	14
15-16	0	0	2	9	9	9	9	9	9	9	9	9	9
16-17	0	0	1	3	6	6							

Priority problems

Specific priority problems

- Lack of intelligent systems to integrate all stress data, Ellipse and Geogis(asset data) to provide decision support information.
- Lack of clarity in TRK/3011 standard especially for stressing in switches and crossings (S&C) Lack of access for maintenance with increased capacity (i.e. Digital railway).
- Lack of suitable training material for stressing competence in S&C
- Lack of non-destructive testing for S&C.
- Poor quality reporting of work or ballast disturbance/deficiency.

Related goals

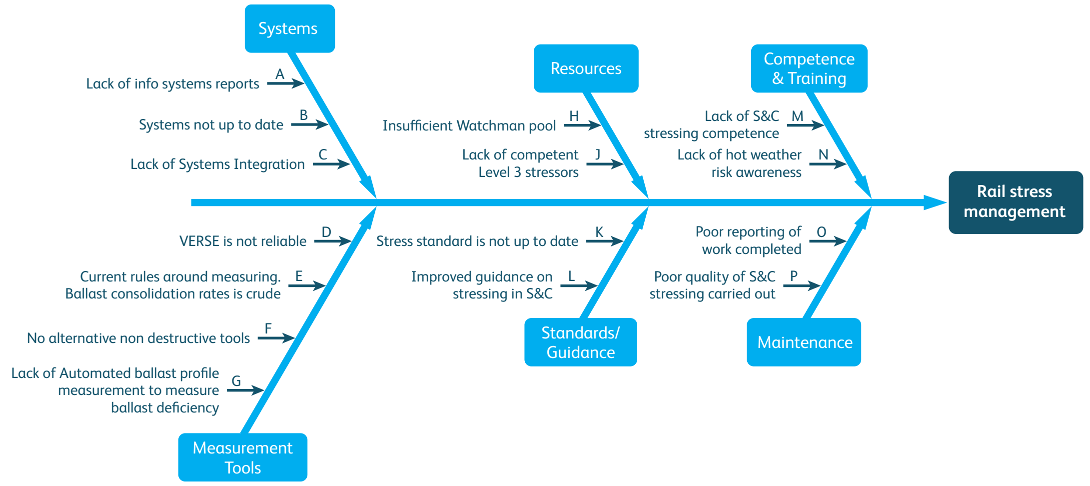
- Develop more effective and integrated decision support tools for rail stress and critical rail temperature management linked to Ellipse.
- Update and publish TRK/3011.
- Improve training material aligned to TRK/3011 standard rewrite.
- Investigate feasibility of non-destructive or autonomous rail stress system/tool for Plainline CWR and S&C.
- Automate reporting of ballast deficiency.
- Improved understanding of rate of ballast consolidation.

Benefits

- Reduction in track buckles.
- Reduction in heat-related train delays.
- Improved clarification of stressing standards and associated training material.
- Safety benefits and efficiency for managing and maintaining rail stress.
- Better quality data to manage hot weather risk.
- Application of improved risk mitigations following disturbance.

Analysis of causes

Top causes of track buckles relate to the lack of measurement tools, systems information, standards update and training.



Scope

Various track data systems require integration to link work activity to rail stress and weather forecasting. This provides support information to maintenance engineers to help them make the decisions to mitigate track buckle risks during hot weather.

Research into alternative, non-destructive testing is a key requirement of this challenge. New tools used to determine residual and actual stress in rails will help to prioritise work and implement appropriate risk mitigation to minimise service disruption. The R&D will also support strategic decisions for more effective maintenance of compressive stresses in the track asset, which will provide whole life cost benefits.

Additional research into ballast consolidation rates, especially on lower tonnage routes, will support work activity planning and delivery. This will help provide robust and effective track solutions maintaining the required performance levels needed to run reliable services.

To address these challenges it is expected that R&D actions will need to address the following issues:

- Are there alternative non-destructive means of measuring rail stress, including residual stresses in the rail from manufacture?
- Can the current systems be better aligned to provide predictive and trend analysis of how the asset performs in certain conditions/with certain features (E.g on high cant curves or in complex S&C)?
- Do we have sufficient understanding of ballast consolidation rates and how this links with compressive stress disturbance in rails?
- Do we understand the gradual rate of loss of compressive stress in rail over the life cycle of the asset?
- Are there ways of automating inspections to provide accurate measurements of deficiencies in the track asset that may result in weaknesses that could lead to track buckles?
- Any research and development around this area may consider prevention of track buckling risk as a whole and does not have to be solely limited to rail stress management.

Expected impact & benefits

- The R&D initiatives included in this challenge will improve our ability to prevent track buckles and train delays.
- Safety and efficiency benefits will also be realised along with improved data quality and system alignment for better decision making.
- Development of a risk matrix relating to management of the track asset in hot weather will help to focus resources and activity on the areas that offer the biggest benefit to safety, performance and resilience of the infrastructure.

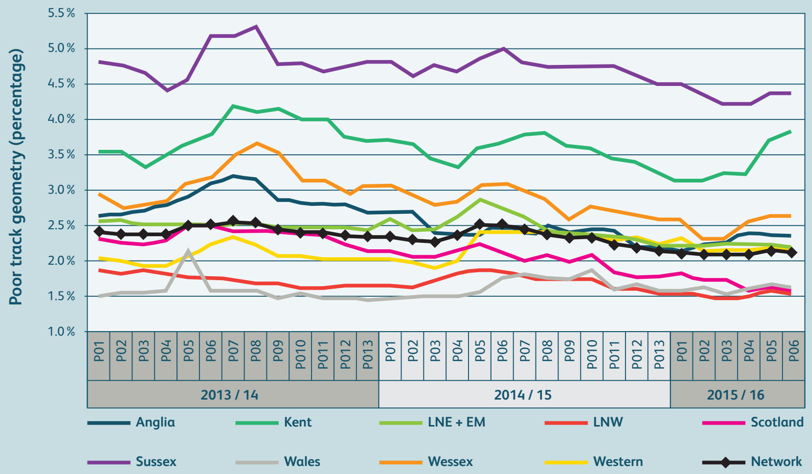
Reliable and resilient track geometry

What is the situation?

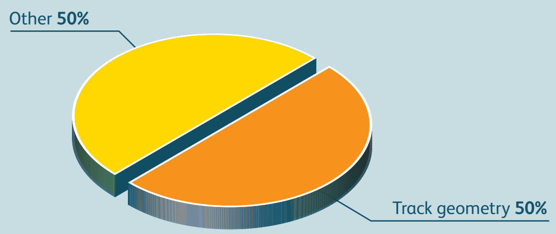
Track geometry resilience is a problem resulting in excessive workload for our maintenance teams and loss of financial efficiency.

Geometry is affected by a number of factors including the condition of rail, pads, fastenings, sleepers, ballast and subgrade. It is monitored by track measurement vehicles (for example the ‘New Measurement Train’) and the data collected is used to inform us where to plan and undertake repair work. The cost of track maintenance equates to 50 % of our total maintenance spend, with track geometry alone accounting for approximately 10 % of the total maintenance spend. Track geometry faults cause poor condition track which can deteriorate resulting in speed restrictions, having a negative impact on train performance and in extreme cases result in derailments.

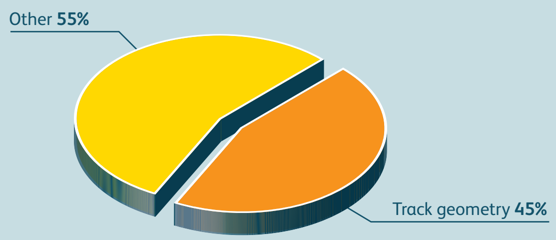
Poor track geometry



Schedule 8 costs for track



Rail Accident investigation Branch (RAIB) investigated derailments causes



Priority problems

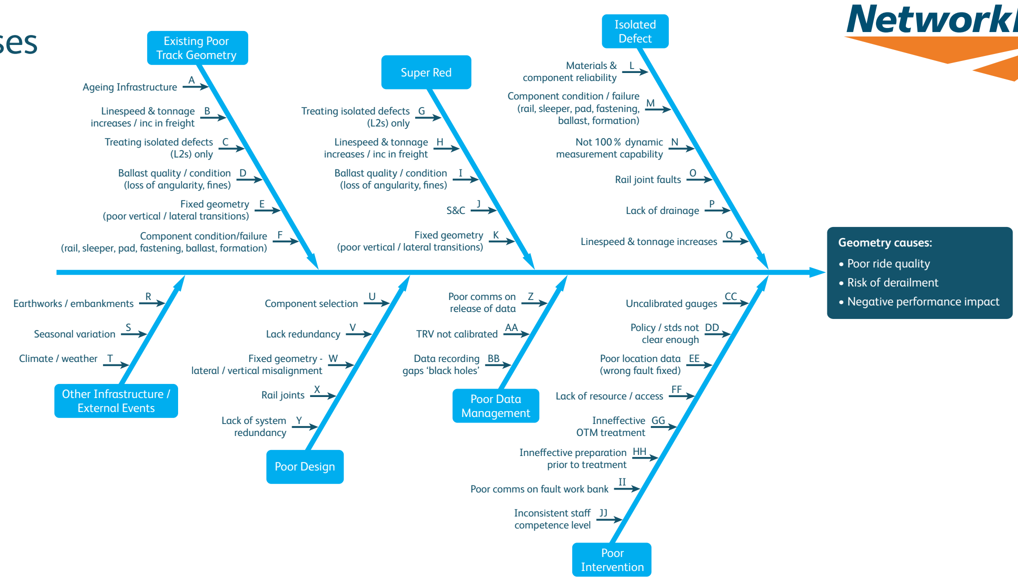
Specific priority problems

- Renewals or Enhancements create future faults.
- Emergency and Temporary Speed Restrictions.

Related goals

- True visibility (management, maintenance, effectiveness).
- More maintenance for same resource (cost and access).
- Open at line speed after renewal / refurbish.
- Over-achieve CP5 targets for track quality.
- 100 % P&P geometry treatment (including RCM).
- Reduction in schedule 8 payments for geometry faults.
- Reduction in repeat visits to the same faults.

Analysis of causes



Scope

A number of innovation and development activities to deliver an improvement in track geometry are required or already underway. Current initiatives include the development of a Track Integrated Geometry Engineers’ Report (TIGER). This will help to align faults with interventions that are undertaken to measure the effectiveness of repairs and evidence complexity of site-specific repairs to make more informed engineering decisions.

Research is required to utilise current data and develop new data streams to improve management visibility and earlier intervention to minimise deterioration. Development is required to improve our capability to predict and prevent track geometry faults which will reduce ‘Schedule 8’ delay minute penalties as well as the amount of repeat work. This will help us achieve our track geometry targets and support the effective delivery of repairs using cost effective methods to deliver improved maintenance within the available access windows.

R&D activities are needed to develop:

- Predictive track deterioration modelling for design and decision support.
- New methods of measuring geometry using in-service vehicles in real-time supported by standardised reporting structures to inform maintenance engineers well in advance of significant faults arising.
- Detailed research into the rate of change of trackform stiffness and associated monitoring systems to deliver improvements in track geometry understanding and repair techniques.

To address these challenges it is expected that R&D actions will need to address the following issues:

- Are the current critical limits and reporting systems used to report geometry thresholds adequate to provide maintenance with sufficient data to predict track condition deterioration more effectively?
- Explore the feasibility of a single source system that is capable of receiving and transferring geometry data from various accelerometers based systems and translate it into meaningful and standard reports for maintenance engineers?
- Explore feasibility of developing a data repository with specified inputs into a railway standard specification and agreed with ROSCOs, TOCs and FOCs in particular for new trains to be fitted with the required technology to provide compatible outputs.
- Further enhancement and improvement are required to deliver higher quality and more frequent and consistent track measurements to improve data quality trending and prevent gaps in asset data reporting.

Expected impact & benefits

- R&D will help to assess the effectiveness of repairs by providing more integration in our information systems.
- Real-time geometry measurement will enhance our trend analysis capability and minimise train disruption using a proactive predict and prevent approach.
- Reduction in track geometry faults will improve train service performance leading to less congestion and better customer satisfaction.
- Better understanding of track geometry behaviour from a combination of factors including track geometry deterioration will support whole life cost analysis.

Re-Profiling Rail to Remove Defects & Extend Rail Life

What is the situation?

Rail grinding was reintroduced in 2003/04 post Hatfield derailment (Oct 2000) to manage the contact stresses that cause the development of RCF cracks, by removing rail and re-profiling the rail head. Grinding can be used to remove light and moderate RCF.

Train borne rail milling is a proven technology not currently used in the UK, which can be used to remove heavy and severe RCF and re-profile the rail.

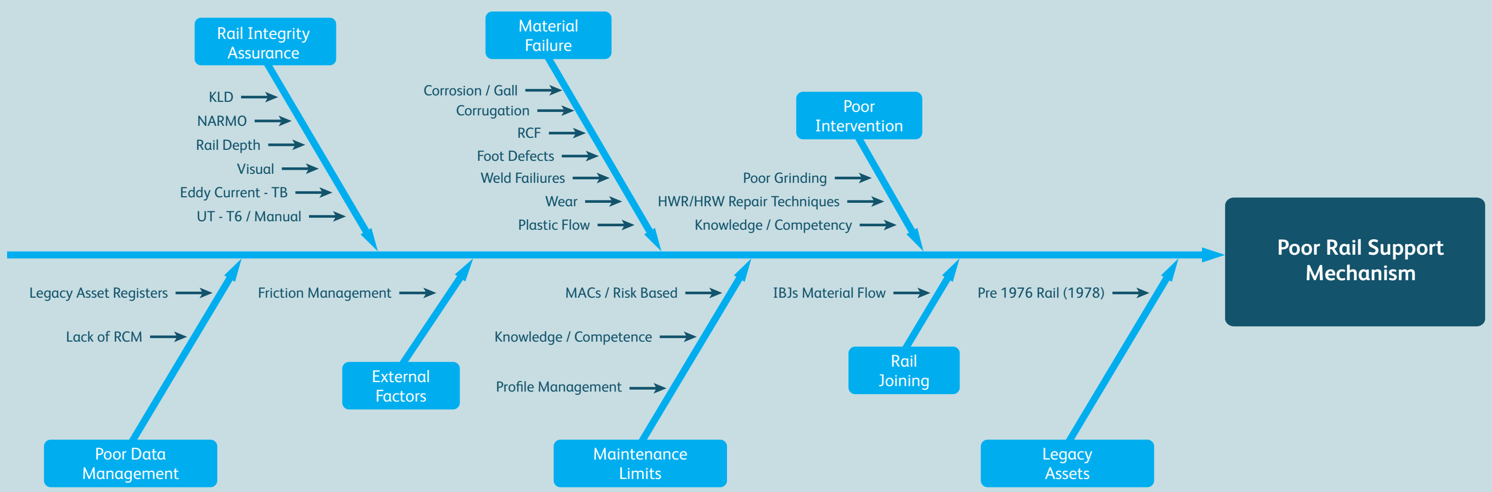
Managing the rail profile using grinding only (light & moderate) provides a potential rail life extension of the order of 3x the unground rail life (Hatfield study). When Hatfield rails were replaced the original rail was treated by rail milling and this proved to give a further life extension of 10 years. This compares with a 4 year life pre-rail profiling.

Proactive management of rail contact stresses extends the life of the rail by:

- Reducing the development of RCF type defects
- Reduces the requirement to re-rail sites with heavy/severe RCF
- Cost effective heavy re-profiling where grinding requires multiple passes

Our approach to rail profile management is "one size fits all" and relies on rail grinding. Using current NDT data and developments in rail grinding and milling technology offers us the opportunity to develop a more targeted approach using both grinding and milling to extend rail life.

Analysis of causes



Priority problems

Specific priority problems	Related goal	Benefit
• Lack of understanding of the rail profile requirements based on a site specific approach means that our "one size fits all" strategy does not maximise rail life.	• Extend rail life which is hindered by inability to adopt site specific approach. • Develop improved process and methodology for managing rail profiles to reduce sidewear, RCF and related rail/wheel damage.	• Condition based rail profile management, leading to more efficient use of rail profiling machines and equipment (rail grinder / milling machine). • Increased rail life due to less re-profiling where this is not needed and through small defect removal.

Scope

The scope of the challenge is to explore how data can be collected and combined so prioritised intervention can take place before failure occurs and manage the conicity to a level before the forces create damage.

The scope covers the development of techniques, processes or systems to help improve extend and monitor rail profiles.

Specific research needs

To address these challenges it is expected that R&D actions will need to address the following aspects:

- Study the effects of grinding profile treatment against changes of rail metallurgy
- Using data available from various inspection techniques develop techniques or systems to manage conicity
- Study the possibilities of material coatings in a rail interface environment
- Study the identification techniques required to capture embryonic defects forming

Speed Restrictions (including speeds caused by cyclic top)

What is the situation?

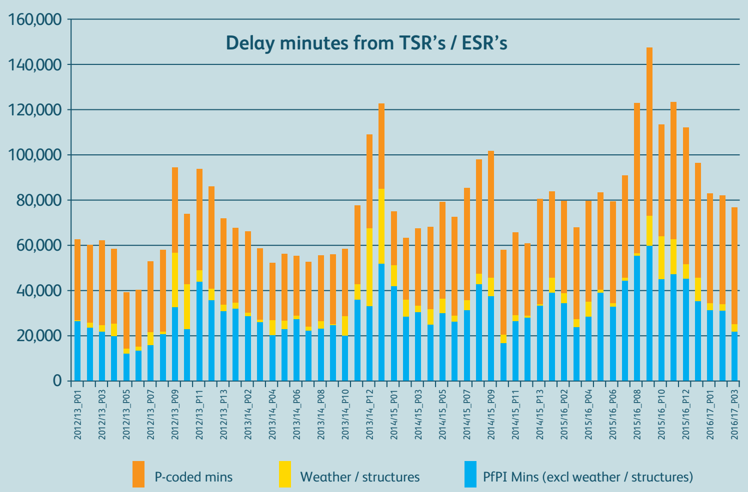
Temporary Speed Restrictions (TSRs) have reached an 8 year high. The main causes of Track TSRs are cyclic top faults, resulting in performance related delays to passenger and freight services. Cyclic top is a set of 3 or more equally spaced geometric wavelength faults which excite train vehicle suspensions (mainly freight), resulting in the risk of derailment.

Our ability to predict or detect cyclic top and other track related faults, which lead to TSRs is inconsistent and has resulted in the rise.

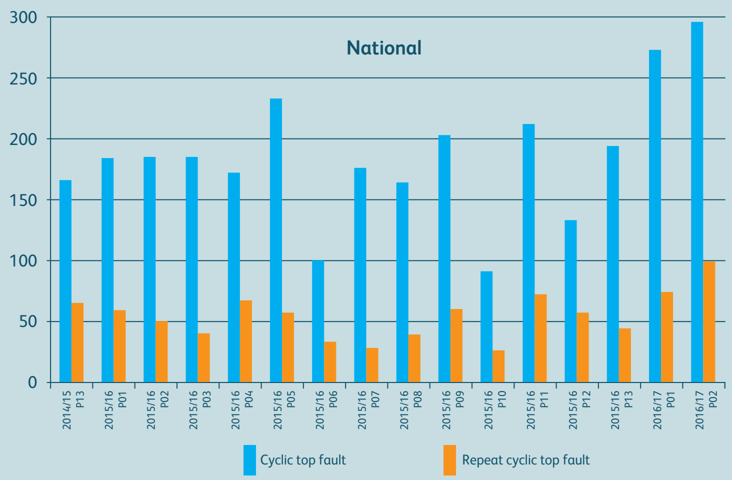
Lack of software to support TSR and Emergency Speed Restrictions (ESR) design on the frontline, results in poorly positioned ESR/TSR equipment, leading to Wrong Side Failures and train delays.

TSR's can significantly affect train services contributing to performance delays, impacting on our customers and affecting our reputation.

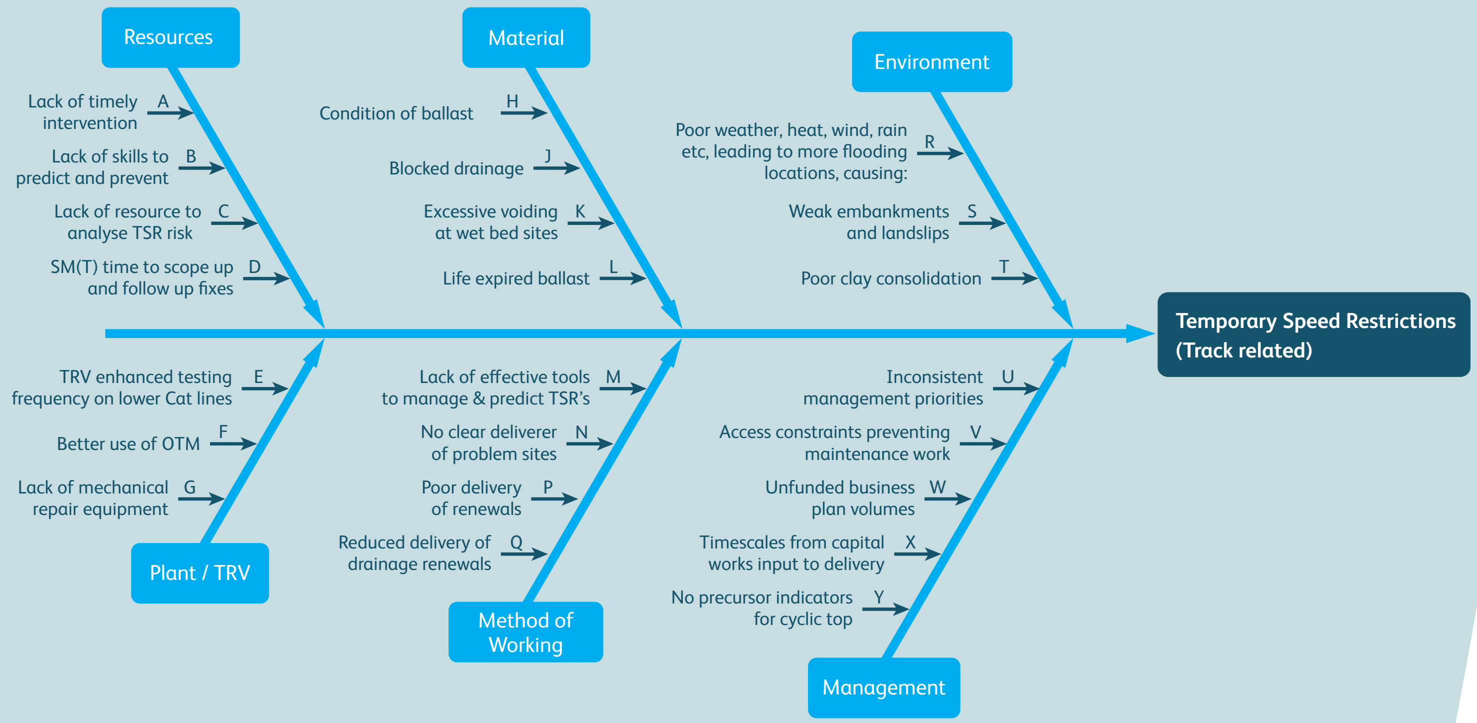
TSR delay min trends from 2012/13



TSR causes two year trend



Analysis of causes



Scope

We need to improve our ability to identify cyclic top faults and other significant geometry faults to reduce unplanned temporary speed restrictions.

In order to enhance this capability, further research is required on the wheel/rail interface and vampire modelling to develop an updated threshold report for cyclic top. This will enable the development of predictive algorithms for cyclic top deterioration.

This will provide decision support information to maintenance engineers to assess the condition and repairs required to eliminate the fault and therefore the risk of a speed restriction being imposed.

It is essential maintenance teams are provided with the relevant skills and tools to perform effective and robust repairs.

Priority problems

Specific priority problems

- Unable to identify sites with risk of TSRs.
- Unable to clearly define root cause of TSR and define action plans to correct.
- Unable to plan and align suitable resources and access to deliver scope.
- Poor positioning of ESR equipment due to lack of ESR design capability and understanding. Also lack of design system for ESRs within maintenance and works delivery.

Related goals

- Early identification and greater visibility of TSR at risk sites to intervene earlier and avoid TSRs.
- Development of tools, information and training material to aid frontline engineers' capability to identify and implement effective controls.
- Develop standardised processes and strategies for more effective and efficient targeting of sites to minimise imposing TSRs.
- 50 % reduction in the number of cyclic top TSRs by end CP5.
- ESR design system for improved management and positioning of ESR equipment to minimise wrong side failures and train delays.

To address these challenges it is expected that R&D actions will need to address the following issues:

- Is the current cyclic top algorithm consistent and accurate enough when aligned with more modern vehicle suspension behaviour?
- If there is a reduced threshold limit to enable earlier intervention to remediate faults?
- Is there sufficient data to produce deterioration trends and predictive reports that will aid more timely planning and repairs?
- Are there means to manually measure cyclic top more effectively with a readily available method of detection?

To improve the design and installation of ESRs, software is required that accurately calculates the positioning of equipment to avoid unnecessary risks to the safe running of trains. This software needs to use our topographical data of the network to account for any track obstructions and conflicts. A visual output to support frontline teams installing equipment at the correct locations would also be of use.

Expected impact & benefits

- The development initiatives will provide predictive information to engineers to enable earlier intervention and deliver robust repairs to prevent TSRs being imposed.
- An improved ESR design system will help improve compliance with standards and reduce the risk of unnecessary failures.
- These improvements will provide a significant benefit to a reliable and safe train service, while improving train performance and customer satisfaction.

Alternative Methods for Patch Repairs in Tunnels

What is the situation?

fig. 1

fig. 2

The rise in passenger and freight traffic means reduced access time for inspection and repair.

The current forecast for 2030 is 34 % increase in passenger traffic and 40 % increase in freight traffic (compared to a 2005 baseline). Reduced possession availability for tunnel remediation will result in more extensive time, cost consuming, complex repairs as these assets get older.

Our current policy is to maintain the tunnels for continued serviceability, extending tunnel service life is seen as a major priority to facilitate the UK and Europe's rail transport ambitions.

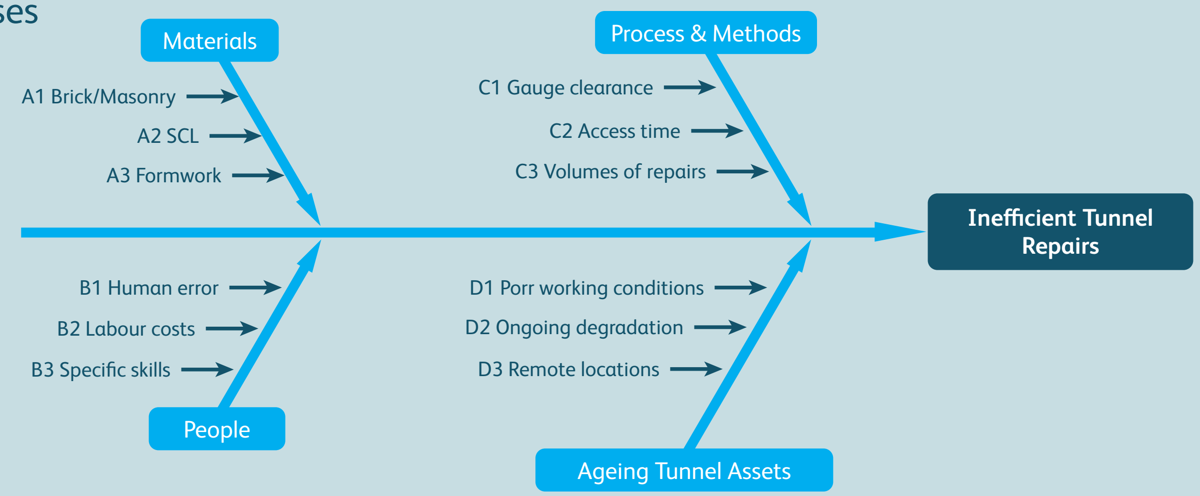
Current repair methods and access arrangements are not appropriate for the forecast demands of the railway.

To appropriately manage the risks associated with tunnel assets, it is necessary to develop new repairing, strengthening methods and materials which cause less traffic disturbance. Fast and safe installation is needed within the short track access times. Using limited materials that require excessive manual handling.

In addition, a number of repairs undertaken currently require formwork, which often impacts on gauge constraints within tunnels, or sprayed concrete which requires specialised equipment and lengthy curing times before reaching full strength.

With future demands on the railway and less access time, it is important that repairs can be carried out as efficiently as possible during shorter possession times.

Analysis of causes



Priority problems

Specific priority problems

- Insufficient access to maintain the tunnels at an efficient rate to maintain serviceability and safety.
- Current repair methods are becoming inadequate given high rate of degradation of tunnel assets.
- Low achievable volumes of maintenance.
- Gauge infringement incidents due to current temporary works measures.
- Large quantity of material required for current repairs.

Related goals

- Repairs can be carried out faster and safer inside shorter possessions.
- More advanced repair materials delivered through efficient means.
- Repairs will have faster application and curing times to allow more repairs to be completed.
- Formwork not required for repairs.
- Minimise materials and equipment needed in the tunnels for repairs.

Benefits

- Reduced railway disruption and lines returned to service quicker.
- Sustainability with maintaining tunnel condition i.e. required level of serviceability as the assets age.
- Reduced overall cost and time taken to carry out repairs.
- Safer and reduces need to re-enter tunnel to remove formwork.
- Reduce manual handling and reduced material cost for repairs.

Scope

Repair materials that can be deployed quickly and safely within tunnels, by non specialised workers, are required to improve efficiency in tunnel repairs. This will reduce the number and length of possessions required to carry out maintenance work.

This new repair method should allow for minimal materials and equipment being brought into tunnels for repairs, shortening the time required to complete a patch repair. Allowing lines to return to operation more quickly.

The improvement works should focus on the replacement of original damaged brickwork with new materials that

should be developed not to degrade in a tunnel environment. Additionally, they must prevent further degradation and avoid the need for additional intervention.

Specific research needs

To address these challenges it is expected that R&D actions will need to address the following aspects:

- How can repairs be carried out faster and safer inside shorter possessions?
- How can innovative repair materials be applied and delivered efficiently?
- Are there innovative solutions that can negate the need for temporary works? What can be done or what alternatives can be used to optimise materials and equipment needed in the tunnels for repairs?

Expected impact & benefits

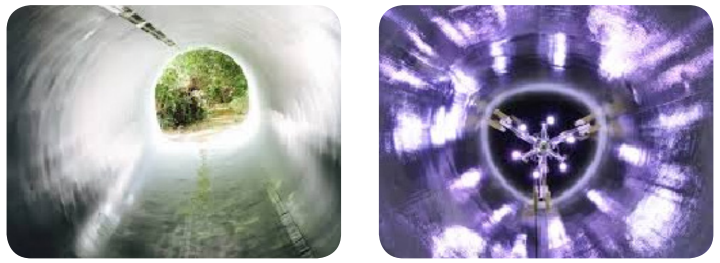
- Reduced railway disruption and lines returned to service quicker.
- Sustainability with maintaining tunnel condition i.e. required level of serviceability as the assets age.
- Reduced overall cost and time taken to carry out repairs.
- Safer and reduces need to re-enter tunnel to remove temporary works.
- Reduce manual handling and reduced material cost for repairs.
- Reduce the reliance on existing diminishing skill sets.

Examples

There are a few concepts under development that could fulfil this challenge statement. Examples shown below include UV liners used in culverts; the material is fed through the culvert via a machine and then enlarged to fit the circumference of the culvert. UV light is then used to strengthen the material providing a new lining with no excavation or maintenance engineers required.

Another option is the use of 3D printed materials, such as titanium, to fit perfectly within repair locations to speed up repairs and make them more accurate for onsite installation. With decreasing number of experienced bricklayers working in tunnels it is important to find solutions that are less reliant on these specialised tradesmen.

Example 1:
UV Culvert Liners used to reline culverts.



Example 2:
3D printed bricks could be used for specific repairs.

Capability Assessment Tool for Tunnel Masonry Linings

What is the situation?

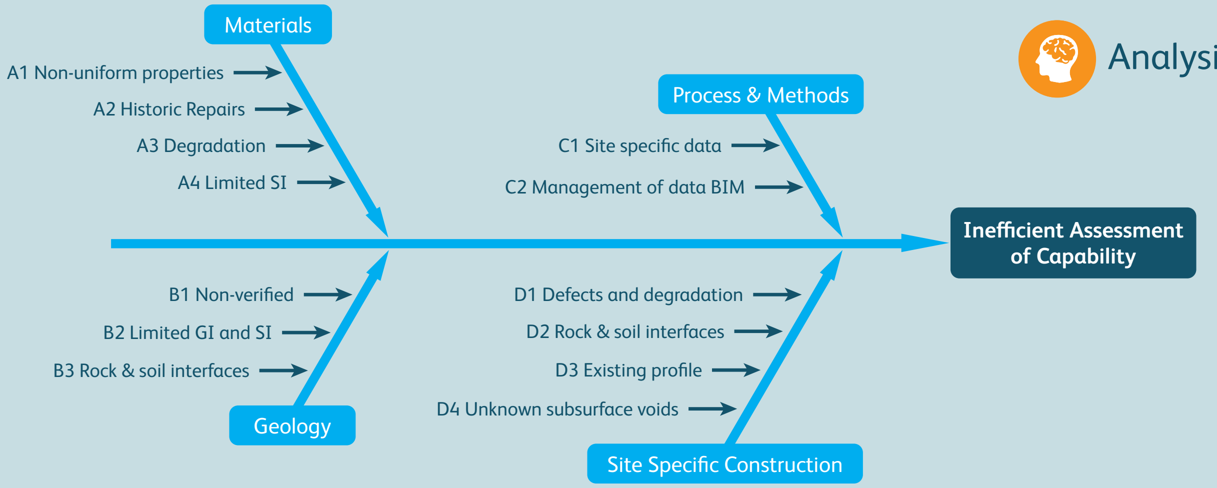
We are responsible for 630 tunnels, stretching over 335 Km throughout the network. Currently, there is no prescribed method for assessing tunnel lining capacity. Interactions with geology , historic repairs and structurally significant defects are currently undetermined.

Track access availability is decreasing, meaning possessions to complete tunnel examination and maintenance is at a premium.

Furthermore, the quality of data collected during examinations and the presence of specific elements within each tunnel, make a universal assessment more complicated than just a data manipulation algorithm.

Achieving a detailed understanding of a tunnel lining capacity is necessary to better manage Network Rail's tunnel portfolio while meeting requirements of the 2030 railway and Digital Rail.

Analysis of causes



Priority problems

Specific priority problems

- Understanding the structural capacity of tunnel lining.
- Quantitative assessment of condition data.
- No prescribed method of tunnel lining capacity assessment.
- Interactions with geology, historic repairs and structurally significant defects are currently undetermined.
- There is a need to detail required on-site data collection to enable the appropriate level of capacity assessment.

Related goals

- A repeatable and reproducible methodology to accurately and objectively manipulate data to satisfactorily determine the capacity of a tunnel lining.
- An appraisal to determine whether action is required to ensure that the level of safety and serviceability of the tunnel remains acceptable.
- Inform and detail adequate intervention works that satisfactorily strengthen the lining capacity.
- Tunnel Information Modelling (BIM for Tunnels) : Shared and collaborative knowledge resource for information.

Benefits

- Facilitate informed asset management decision making.
- Less cost impact.
- Improved risk evaluation of serviceability and structural stability of operational tunnels.
- Less disruption for the TOCs.

Scope

We need to establish qualitative and quantitative assessment methods for masonry lined tunnel major elements.

To support this challenge and manage the risks associated with tunnel assets, it will be necessary to develop techniques to undertake tunnel 'assessments' and develop the tools to adequately analyse and assess lining capacity.

The chosen analysis methods must be partnered with 'big data' management system such as Building Information Modelling (BIM). This will enable the interpretation and analysis of the information which is generated to positively inform decisions in the ongoing management and optimise of tunnel assets.

This may go further and include organic architecture with computer systems utilised to interrogatethe data.

Specific research needs

A quantitative assessment of the strength of tunnel linings and its adequacy to support neighbouring land is required.

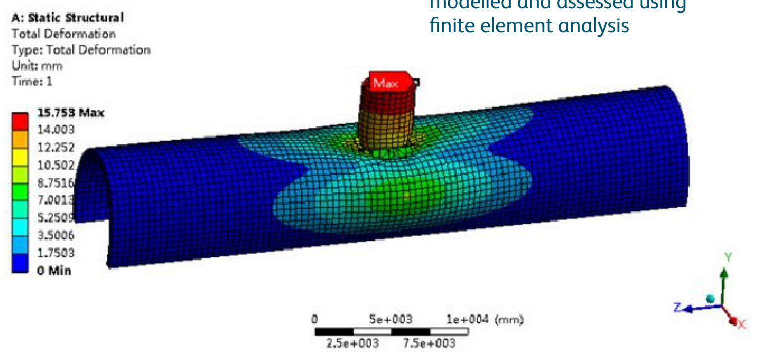
Assess individual tunnel major elements for durability and capability. With full consideration given to permanent and transitory actions, principal dimensions, condition data, material properties and geotechnical parameters.

Furthermore, the tunnel assessment should inform the management of the structure by quantifying tolerable changes in the condition, in terms of the strength of the lining element; specifying sufficient strengthening works and determine the adequacy of the major element and structure as a whole.

Related data

Each tunnel asset is sub-divided into components such as bores and portals. Tunnel bores are broken down into lengths termed tunnel sections. Also termed major elements within the Tunnel Condition Marking Index (TCMI) scoring system.
These are split horizontally to form smaller discrete areas known as minor elements for condition reporting at a higher resolution (Fig1).

fig. 1 Example of how tunnels can be modelled and assessed using finite element analysis



Expected impact & benefits

Understanding the capacity of constitute minor elements is required to help determine integrity of the tunnel and whether a deterioration in condition is tolerable, or whether specific interventions are required to maintain the tunnels ongoing fitness for purpose.

High Output Tunnel Repairs and Enlargement

What is the situation?

fig. 1

Access time for inspection and repair is reducing as railway passenger and freight traffic continues to rise.

The current forecast for 2030 is 34 % increase in passenger traffic and 40 % increase in freight traffic compared to a 2005 baseline. Reduced possession availability to accomplish tunnel remediation will result in more extensive time, cost consuming and complex repairs as assets get older.

Replacement of tunnels is uneconomical. Our current policy is to maintain the tunnels for continued serviceability. In view of this, the proactive and effective maintenance and upgrading of these structures to extend service life are seen as a major priority to facilitate the UK and Europe's rail transport ambitions.

To appropriately manage the risks associated with tunnel assets, it will be necessary to develop new repairing, strengthening and upgrading methods which cause less traffic disturbance. Fast installation is required due to short track access time.

Current repair methods and access arrangements aren't appropriate to meet predicted railway use. Furthermore, gauge constraints within tunnels prohibit line speed improvements, gauge enhancement and electrification projects; and the necessity for tunnel enlargement is growing to allow future increases in railway utilisation.

fig. 2

Priority problems

Specific priority problems

- Insufficient access to maintain the tunnels at a sustainable rate to maintain serviceability and safety.
- Current repair methods are becoming inadequate given high rate of degradation of tunnel assets.
- Low achievable volumes of maintenance.
- Linespeed improvements, electrification and gauge enhancement requirements for larger bores.

Related goals

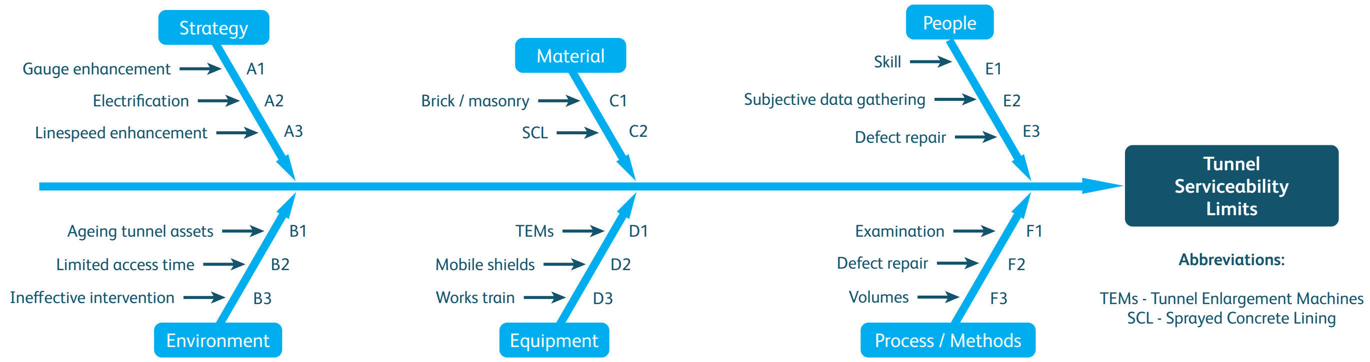
- Equipment to maintain adjacent line open, therefore higher repair outputs can be achieved.
- More advanced repair materials delivered through mechanised means.
- High output tunnel repair methods.
- Tunnel enlargement machines that enable tunnel enlargement that support the higher track utilisation in the future.

Benefits

- Reduced railway disruption during maintenance work.
- Sustainability with maintaining tunnel condition i.e. required level of serviceability as the assets age.
- Reduced overall cost of repair per square metre.
- Reduced railway disruption during work by implementing tunnel-in-tunnel concept. Compliance with technical specifications for interoperability for Interoperability. In line with our strategy streams.

NetworkRail

Analysis of causes



Scope

Staged methods with minimum disturbance to traffic must be developed for the replacement and strengthening of tunnel linings. Additionally, a concept based on mechanisation, with whole tunnel improvement should be developed. The method should allow trains to run, following a tunnel-in-tunnel method for improvement works or adjacent line open for maintenance works. These would allow 24hour work time, as traffic is protected from work zones. The improvement works would focus on the replacement of original lining.

Specific research needs

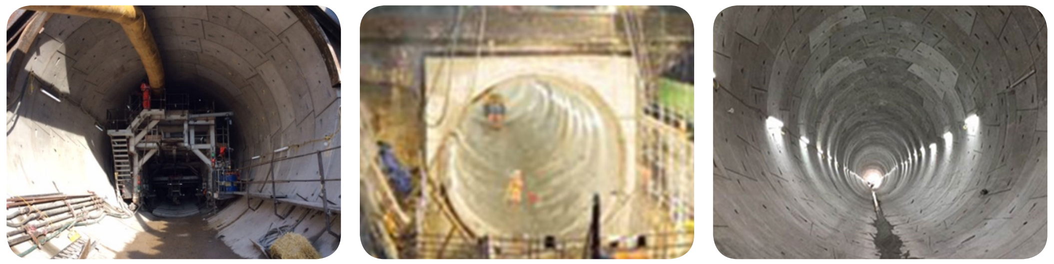
To address these challenges it is expected that R&D actions will need to address the following aspects:

- How can tunnel relining be carried out with minimum impact to rail traffic, taking into account the need for a continuous power supply to train traffic from both overhead and 3rd rail?
- What alternative method of gauge enhancement and tunnel lining replacement could be implemented to arrest condition of an ageing and degrading asset?
- How can large scale maintenance to brick lined tunnels be carried out, whilst having the minimum impact to services?

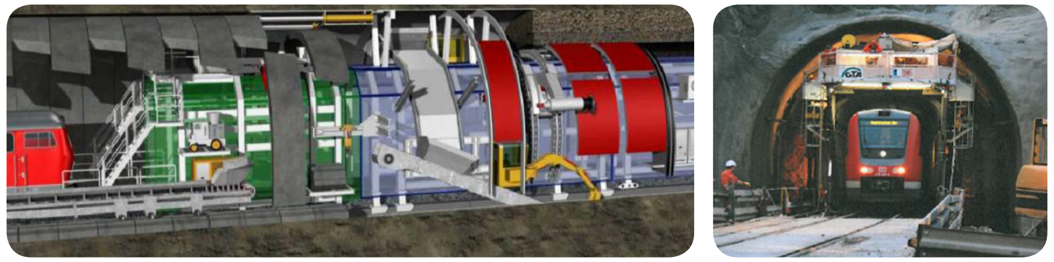
Expected impact & benefits

- Tunnel linings replacement can be programmed to arrest the degradation of an ageing asset.
- Allows tunnel re-lining to be carried out without the need for long blockades.
- Reduces the need for emergency access to the railway for urgent defect repairs, avoiding impact to services.
- Less water ingress that causes defects to other asset types, e.g. OLE and track.

Farnworth Tunnel
Open face tunnelling, long blockade required.



Tunnel Enlargement Machines
Tunnel-in-tunnel concept, maintain railway operation.



Surface Condensation Reducing Slip Resistance

What is the situation?

Network Rail directly manage 21 stations – including Birmingham New Street, Manchester Piccadilly, Edinburgh Waverley, Glasgow Central, Leeds, Bristol Temple Meads and 10 in London. These stations typically have a concourse area and platforms with an overlay of terrazzo, paving or asphalt.

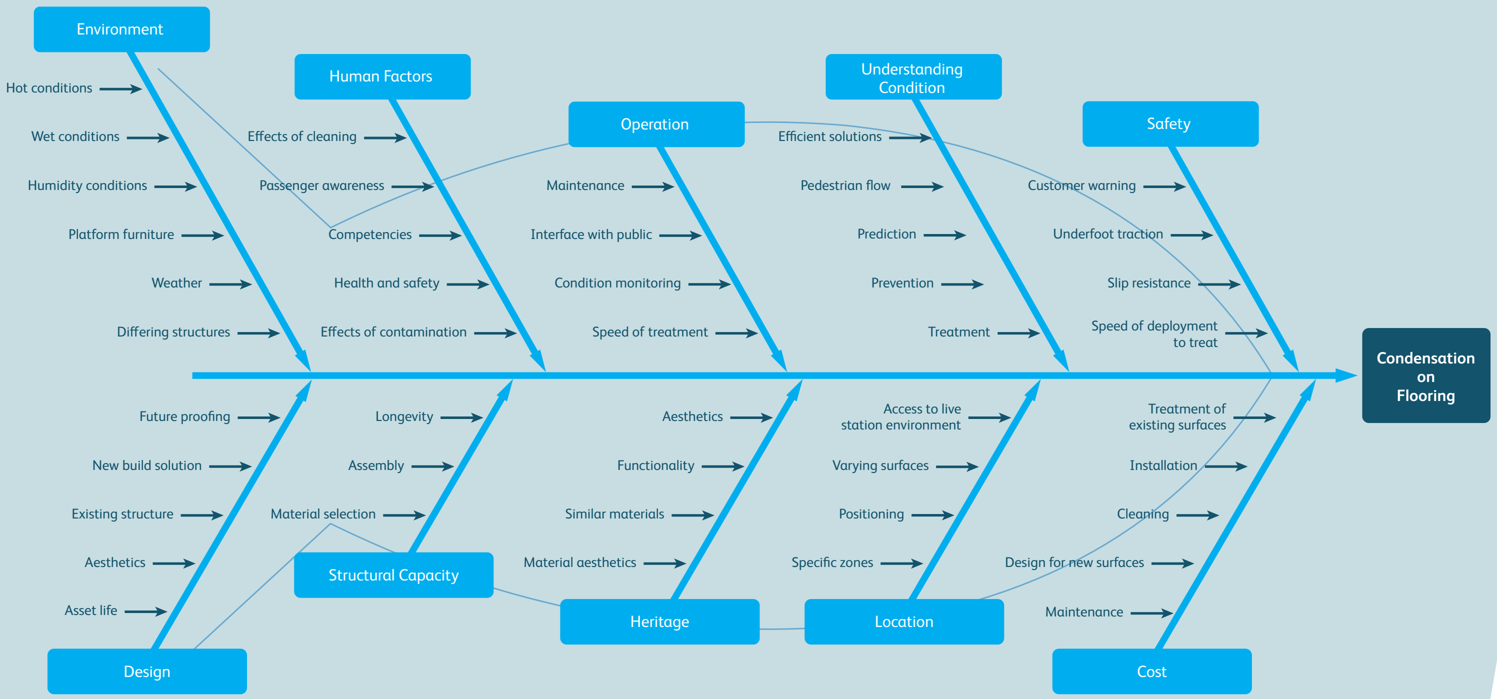
Specific atmospheric conditions will cause these surfaces to “sweat” as moisture within the air condenses as the dew point is reached, which in turn reduces the slip resistance of the flooring increasing the risk of slip related accidents. This can also affect elevated structures such as footbridges and mezzanine floors.

fig1.

fig2.

fig3, fig4.

Analysis of causes



The fishbone (or equivalent diagram) should convey the root causes of the challenge. The use of the RAG process should draw attention to the Top Causes.

Priority problems

Specific priority problems	Related goal	Benefit
a. Prediction	• Provide automated early warning when dew point is likely to be reached so facility operators can take appropriate action and deploy resources.	• Timely deployment of resources & counter measures to reduce risks.
b. Treatment	• Coatings that can be applied to a range of surfaces that limit or prevent change of the slip resistance under wet conditions.	• Reduction of slip risk.
c. Prevention	• Design solutions to prevent condensation issues to new build structures occurring.	• Removal of slip risk.

Scope

The scope of this challenge statement is to investigate methods of prediction, treatment and prevention of condensation on floors at our Managed Stations.

a. Prediction; To understand route causes and through monitoring predict when the dew point is likely to be reached and condensation occur.

b. Treatment; Investigate treatments that can be applied to existing structures to prevent or limit the effects of condensation, these may be active or passive in nature. Where this is impractical look at systems could be quickly deployed to treat areas effected to mitigate the risk of slips, trips and falls.

c. Prevention; Investigate materials and systems that could be incorporated into new designs to prevent occurrence.

Specific research needs

To address these challenges it is expected that R&D actions will need to address the following aspects:

- To understanding the root cause of condensation on a variety of flooring surfaces in similar open spaces, and methods in use to treat these. The design of new structures to eliminate the risk of condensation. Treatment to existing surfaces or mechanical methods to reduce the effects in an operational station.

Road Vehicle Incursion

What is the situation?

An encroachment of a vehicle or part of a vehicle over the boundary between Network Rail and any third party at an overbridge or neighbouring site.

There are 3 primary types of area where RVI (Road Vehicle Incursion) is possible. These are:

- Overbridge sites carrying single carriageway roads, dual-carriageway roads and motorways
- Neighbouring sites where road and rail are beside each other
- Areas adjacent to a railway line where vehicles regularly park

RVIs represent both a risk to railway users and vehicle users using infrastructure in close proximity to the railway.

Whilst there can be a large and varied reasons why a vehicle can become errant, the most severe incidents occur when the vehicles are not contained to entering the railway

fig1. 10,620 identified adjacent RVI sites

fig2. Infrastructure damage following vehicle collision

Analysis of causes

Threat	Barriers to failure								Event
Vehicle Impact (non-track borne)	Design & Construction	Manage Ad - hoc reports	Carry out RVI assessment	Manage RVI incidents	Carry out Examinations	Structural Assessment	Routine Maintenance	Demolish or remove from service	Functional Asset Failure
External threat from adjacent infrastructure	Asset stock not designed to modern standards	Incidents not typically at reoccuring locations	Large volume of sites			Unsuitable assessment tools	Difficult and expensive to increase capacity		Asset is not safe to use

Priority problems

Specific priority problems

- Vehicles entering the railway environment
- High number of sites still requiring mitigation measures
- Alerting railway when boundary is breached

Related goal

- Provide restraint to errant vehicles
- Stop vehicles in close proximity to the railway
- Restrain vehicles in areas with little available space
- Reduced cost of RVI mitigation
- Automated system to inform railway of incidents

Benefit

- Safety benefit – stop vehicles reaching the railway
- Cost saving enabling more sites to be mitigated
- Safety benefit – Preventing trains striking vehicles on the track

Specific research needs

To address these challenges it is expected that R&D actions will need to address the following aspects:

- Solutions which prevent vehicles entering onto the railway environment which can contain the largest vehicles on the road network.
- Difficulties in attaining full network coverage. Lack of technology to identify RVIs from imagery and physical sensors will require significant infrastructure to enable remote monitoring (power and telecoms).
- What preventative technologies are available which improve on conventional solutions and are less expensive? Is there technology used in a different industry which could be developed and applied to this challenge?

Expected impact & benefits

- Methods of identification for where road vehicle incursions can happen (i.e. technologies that can identify the geographical location of those sites)
- Novel technologies for capturing location and risk data based on road and rail configurations
- Digital recording of risk assessments
- Means of protecting the railway from vehicle incursion, beyond what is currently used
- Remote technology to record and notify following collision / damage of a boundary measure (e.g. a fence)
- Identifying cost efficient re-enforcement measures

Maintenance Reduces Availability

What is the situation?

For rolling stock and on-track machines to be effective and efficient they need to be maintained, this however has an impact on availability.

Direct maintenance costs make a significant contribution to an asset's cost of ownership. While this is an obvious cost, when it comes to maintenance there are other costs that are equally important and can have a bigger financial impact on the asset's ownership – reduced availability.

Reduced availability is impacted by planned and unplanned maintenance. Planned maintenance covers periodic inspection, upgrades to software and hardware and overhauls, and can also be termed as preventive maintenance. Unplanned maintenance includes fault repairs and accidents which contribute to asset downtime. These unplanned stops are often caused by operator errors, poor planned maintenance or poor reliability either mechanical, electrical or software.

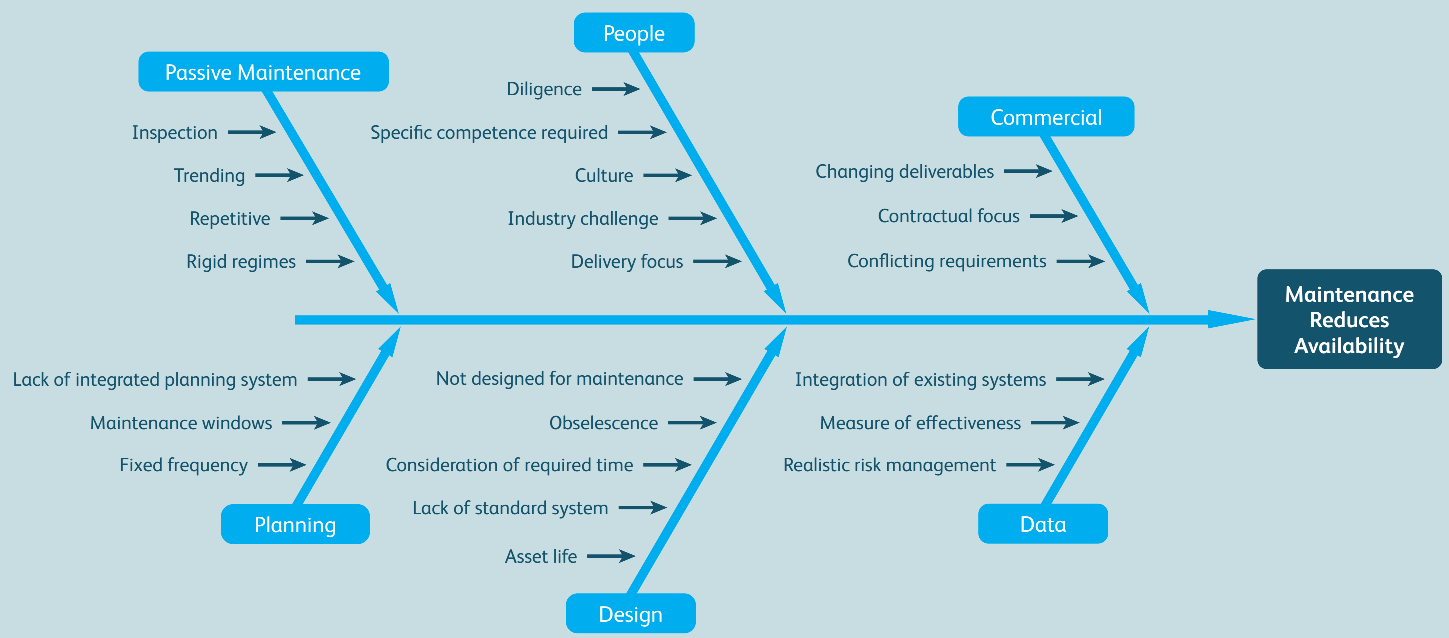
Another contributor to reduced availability is equipment obsolescence which represents a significant risk to operations of older fleets. Machine that are 10-15 years old are more prone to break down easily and require more maintenance. A risk audit can highlight problems and helps to be prepared when maintenance reduces availability. However, access to legacy information is needed to narrow the windows of expected breakdown and give a better time frame for essential maintenance.

It is important to adhere to maintenance schedules to ensure effective asset utilisation and reducing the possibility of unplanned stops. But is there opportunity to limit maintenance outages and optimise availability without agitating unplanned maintenance?

Manufacturers are looking into low-cost condition monitoring systems that enables predictive maintenance. This is empowering operators to be able to diagnose and fix their assets. How effective is this for a diverse collection of rail vehicle fleets?

Running an asset until it breaks trying to minimise 'maintenance reduces availability' will end up having even more serious break downs and longer outages. Preventive maintenance is very important as being proactive has been proven to be more effective than reactive. But what is the optimised level of proactive interaction required?

Analysis of causes



Scope

The overall scope of the challenge is to investigate the potential of new technology and techniques to reduce the maintenance time and improve scheduling of the maintenance regime, hence reducing overall downtime. The enablers for this are:

- Optimised design.
- Real-time understanding and control of maintenance procedures.
- Modern techniques for maintenance scheduling.

Priority problems

Specific priority problems	Related goal	Benefit
• Unknown effectiveness of planned maintenance.	• Have efficient maintenance plans and be able to plan resource effectively into maintenance contracts.	• Optimised maintenance and efficient use of funds.
• Unplanned maintenance causing spontaneous operational challenges.	• 100 % performance and manage the required maintenance outages without causing operational performance uncertainty.	• Reduced downtime and resultant delay costs.
• Assets requiring excessive maintenance. Low operation to maintenance availability ratio.	• Removal of obsolescence by design and acquisition of low maintenance assets.	• Reliable assets with reduced maintenance outages, allowing for increased productivity of assets.

Specific research needs

- Design and development of new tailored tools to optimise maintenance tasks.
- Determine real time health of assets and maintain it as required in service through collection, storage and analysis of data.
- Review what has been done in other industries and determine whether any of these solutions can be used for the rail industry.
- Fail safe asset systems which increase resilience of asset during operation.
- Predictive maintenance tools to eliminate unplanned maintenance.
- Development of smart facilities that automatically inspect health and maintain the assets.
- Assessment tools to determine maintainability of asset through its life cycle.
- Development of assets that are effective, efficient and require minimal maintenance throughout their life.

fig. 1

Expected impact & benefits

- Efficient whole life cost of asset through reduced maintenance.
- Improved availability providing planning flexibility.
- Efficient utilization of the assets.
- Effective maintenance plans which ensure reliability of asset whilst optimising availability.

Mining Ground Investigations

What is the situation?

The UK has a wide range of mineral deposits which have been, and in some cases continue to be, exploited by a variety of mining methods determined either by the type and configuration of the mineral deposit or the technology available at the time of mining. The legacy of this mining activity is that there are numerous caverns, voids, broken ground, tunnels, shafts and adits in the vicinity of the railway. Underground workings, particularly where shallow, may collapse and cause surface settlement, and if this occurs in close proximity to the railway corridor it can have a significant impact on both the safety and performance of the railway.

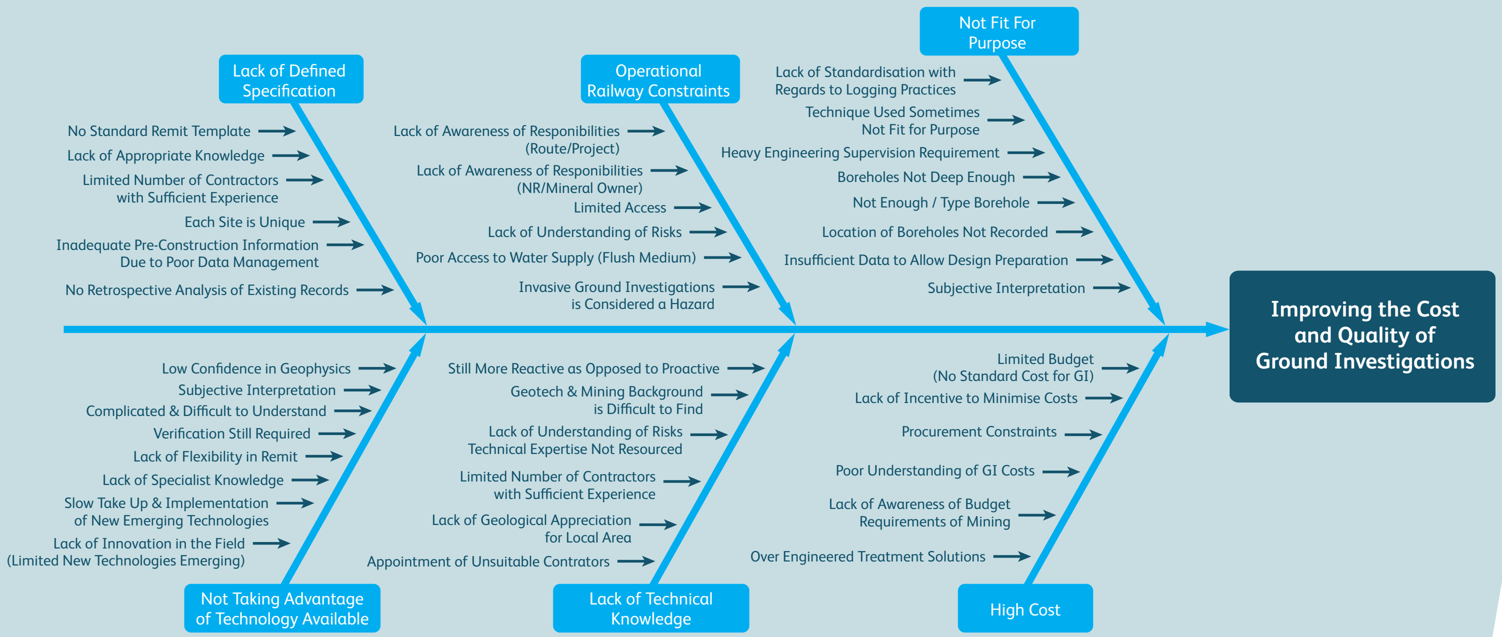
Existing Network Rail records indicate that there are in excess of 5000 known shallow mining hazards near the railway, which includes both mine workings and mine entries. Network Rail are in the process of risk ranking all of the known shallow mining hazards in order to prioritise pro-active investigation and treatment. There is an obligation to provide adequate permanent and sustainable mitigation for at least the 20 % of the high risk sites by the end of CP6 and provide suitable interim risk mitigation to all other high risk sites during CP6.

Each of the high risk sites will require a desk study, which in many cases will recommend that ground investigation be carried out. The three primary objectives of the ground investigations are (1) to establish the nature, condition and extent of the mining hazard (2) establish the condition of the surrounding strata and any effects on existing railway infrastructure (3) to provide adequate data for the design of any mitigation measures that may be required.

Undertaking conventional mining ground investigations in the vicinity of an operational railway can be very challenging, this is primarily due to access restrictions and limited possession times. This often results in higher than expected costs and concessions being made with respect to the techniques selected and the quality of data obtained.

In order to meet our obligations within the available budget and timescale, significant improvements need to be made to our ground investigation practices. To meet this challenge we must develop innovative ground investigation strategy that draws on both new and existing technologies.

Analysis of causes



Priority problems

Specific priority problems

- Mining ground investigation on the railway is expensive.
- Often not fit for purpose, inappropriate techniques used.
- Failure to embrace new technologies and lack of innovation in the field.

Related goal

- There is an obligation for all routes to provide adequate permanent and sustainable mitigation for at least the 20 % of the High Risk sites in their route area by the end of CP6.

Benefit

- Network Rail will be able to meet it's obligations within budget and timescale.
- Improvements in the quality of ground investigation data feeding into the design of mitigation measures.

Specific research needs

In order to address the challenge, it is anticipated that a study will be completed and a report prepared that includes but is not limited to:

- An overview of the types of hazards associated with historic shallow mining that require investigation.
- Overview of key legislation, guidance documents and Network Rail standards and specifications applicable to mining ground investigations in the vicinity of the railway.
- Overview of health and safety legislation and best practice relating to ground investigations.
- Identification of the data outcomes required from ground investigation to inform the design of mitigation solutions.
- A review of current ground investigation practices employed by Network Rail to evaluate mining hazards ideally based on recent case studies relating to both coal and metalliferous mining.
- Identification of ground investigation solutions for shallow mining and mine entry hazards drawing on both new and existing technologies. In developing these solutions consideration must be given to the constraints associated with carrying out a ground investigation in a railway environment. Ideally the ground investigation solutions identified should fall within the following categories:
  1. Direct methods of ground investigation (Example research areas might include: rotary open hole techniques, cored boreholes, sonic drilling).
  2. Geophysical methods (Example research areas might include: Micro gravity, electromagnetic, magnetic, resistivity, ground penetrating radar, seismic, borehole geophysics etc).
  3. Other means of investigation (Example research areas might include: Underground surveys, subsurface laser scanning, aerial and satellite data).
- A set of recommendations for a ground investigation strategy.
- A cost/benefit exercise comparing existing practices with the recommended.

Mitigation of Shallow Mining Risks

What is the situation?

The UK has a wide range of mineral deposits which have been, and in some cases continue to be, exploited by a variety of mining methods determined either by the type and configuration of the mineral deposit or the technology available at the time of mining. The legacy of this mining activity is that there are numerous caverns, voids, broken ground, tunnels, shafts and adits in the vicinity of the railway. Underground workings, particularly where shallow, may collapse and cause surface settlement, and if this occurs within close proximity to the railway corridor it can have a significant impact on both the safety and performance of the railway.

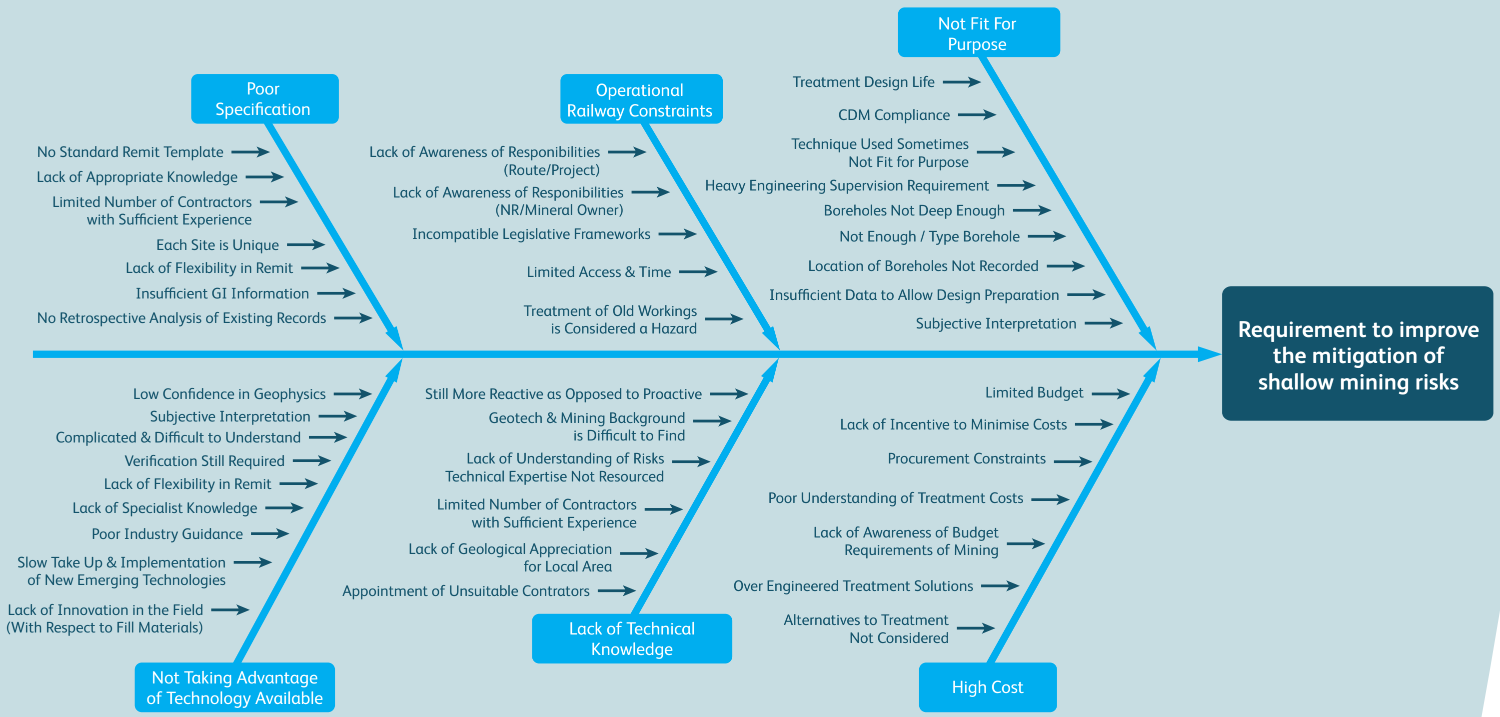
Existing Network Rail records indicate that there are in excess of 5000 known shallow mining hazards near the railway, which includes both mine workings and mine entries. Network Rail are in the process of risk ranking all of the known shallow mining hazards in order to prioritise pro-active investigation and treatment.

Each of the high risk sites will require a desk study, which in many cases will recommend that site investigation be carried out. Following site investigation it is expected that mitigation measures will need to be designed and implemented for a significant number of the high risk mining hazards.

Historically the mitigation of shallow mine working hazards beneath the railway has involved ground consolidation, whereby grout is injected under gravity pressure through boreholes to fill any sub-surface voids so that sub-surface support lost by excavation can be replaced or maintained. This type of mitigation has proven to be very expensive in a railway environment.

In order to meet our obligations within the available budget and timescale, significant improvements need to be made to our mitigation practices. To meet this challenge we must develop a new mitigation strategy, that utilises innovative solutions drawn from both new and existing technologies.

Analysis of causes



Priority problems

Specific priority problems

- Treatment of shallow mine workings and mine entries on the railway is expensive.
- Sometimes not fit for purpose, inappropriate techniques used.
- Failure to embrace new technologies and lack of innovation in the field.

Related goal

- There is an obligation for all routes to provide adequate permanent and sustainable mitigation for at least the 20 % of the High Risk sites in their route area by the end of CP6.

Benefit

- Routes will be able to meet their obligations and the risks posed by shallow mine workings to the railway will be significantly reduced.

Specific research needs

In order to address this challenge, we are looking for expressions of interest relating to the research and development of:

1. Ground consolidation (Examples of research areas include: drilling and grouting techniques and materials, potential use of secondary aggregates, foam injection etc).
2. Bulk filling (Examples of research areas include: the potential application of 'paste' technology).
3. Bridging techniques (Example research areas include: installation of concrete slabs beneath the track, the use of geogrid).
4. Sub-surface ground control measures (Example research areas include: stowing of old workings,installation of support in old workings e.g. roof bolts, pillar reinforcement).
5. Non-physical mitigation measures (Example research areas might include: monitoring for precursory movement, the potential use of other monitoring technologies such as satellite data).

Fig. 1 - Construction of the shaft cap at Low Moor Station near Bradford

Operations

What is the situation?

Operations relies on front line staff having the data, tools, equipment and systems to make informed decisions to manage the operational, safety and performance risks. There are a number of factors to considers for the operational challenge.

Firstly the challenge is to reduce the risk to employees working on the infrastructure from being hit by trains due to operational errors. There is also a significant risk to members of the public from poor decision making at level crossings, during dispatch duties and when trespassing on the infrastructure.

The next element is the train accident risk and the potential for collisions, derailments or other operational incidents caused by decisions made by operational employees.

Finally the workload of operational employees is increasing with larger areas of control and additional systems and may lead to distraction or poor decision making. The challenge is to effectively manage these risks to staff, passengers and trains through the automation and integration of operational systems to reduce the chances of human error due to poor information or excessive workload.

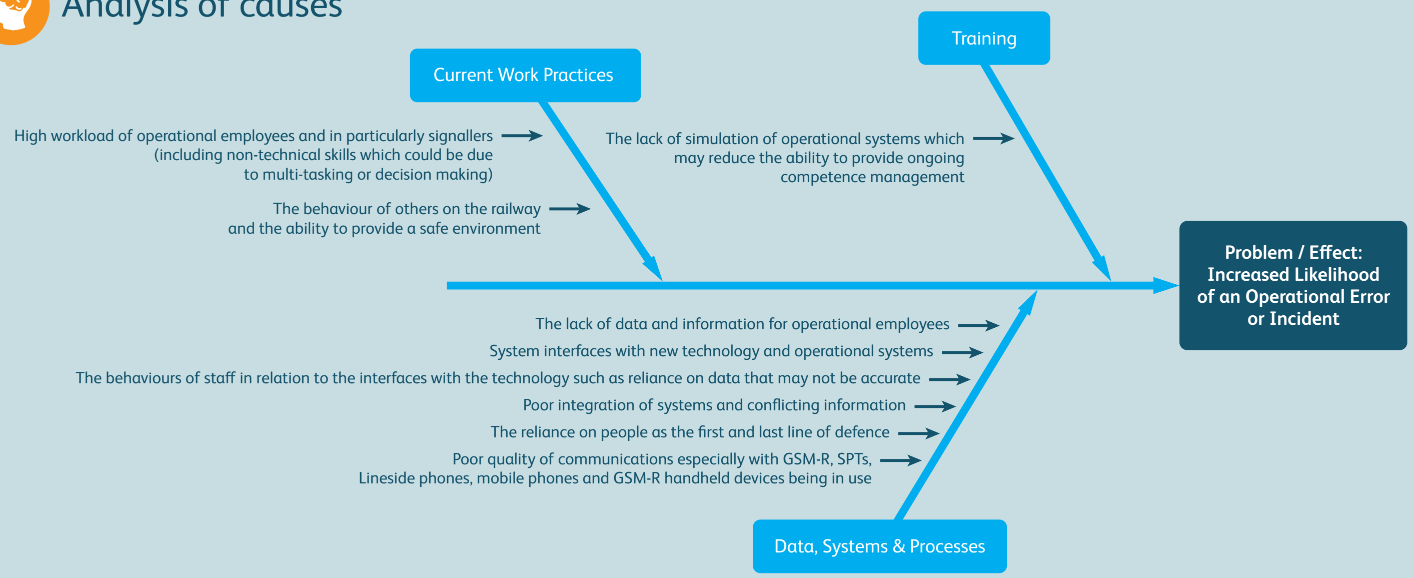
The primary objectives are as follows:

- Reduce the potential for operational errors made by Signallers, Electrical Controllers, Route Controls, Station Staff and Mobile Response Staff.
- Reduce the number of Operational Close Calls within the following categories:

Category	Definition
Protection	An OCC involving the work group (e.g. Controller of Site Safety (COSS) or a lookout) which results in incorrect or inadequate implementation of a line blockage, working outside of the protection limits or removal of protection.
Possession	An OCC involving implementation of a possession (i.e. Person In Charge of a Possession (PICOP), Engineering Supervisor, Nominated Person) which results in the incorrect placement of protection, inadequate or incorrect protection arranged, or irregularity in the removal of protection.
Operating	Any OCC as a result of an operator (e.g. a signaller or controller) giving permission for protection to be laid with a train not yet having passed the site of work; signalling a train into a possession / line blockage, vehicles or pedestrians trapped between gates at a level crossing or given permission to cross when the line is not clear; failure to caution trains; miscommunication when the signaller is in the lead; two trains in section; train routed into an isolated section, switching incident.
On Track Machine or Plant / Engineering Train / Equipment	Any OCC involving on track plant or engineering trains or involving incorrect use or placement of equipment or materials, for example unauthorised movements within possessions, machines or plant overturning, unsafe operation of machines or plant, equipment or materials fouling the running line, irregularities involving scaffolding on.

- Provide the required information to operations staff to allow informed decision making during normal and abnormal operational situations.
- Provide systems that automate the decision making processes to remove the potential for human error.
- Develop systems that do not adversely impact on the workload of operational employees.
- Provide systems that allow the operational teams to Predict, Prevent, Respond and Recover to various operational scenarios.

Analysis of causes



NetworkRail

Priority problems

Specific priority problems

- The operation of User Worked Crossings and the Signaller interface
- The management of line blockages to prevent trains being signalled into protected areas.
- The management of possessions to reduce the risk of points being run through incorrectly placed protection or collisions between vehicles.
- The management of CCTV crossings to assist Signallers identifying objects through technological solutions.
- Management of degraded situations to the signalling system, switches & crossings, electrical systems and track.
- The management of isolations and areas blocked to electric traction
- The visibility of trains on the signalling system, especially in long signalling sections or during failures
- The management of systems to improve the ability to conduct robust safety critical communications and allow robust monitoring
- The management of the risks associated with passengers self-evacuating

Related goals

- Reduction in train accident risk.
- Improvement in workforce safety.
- Improvement in performance management.
- Reduce the risk to members of the public on railway infrastructure.
- Reduce the impact of reputational risk associated with operational scenarios.
- Allow more robust demonstration of our compliance to the legal framework.
- Better meet the expectations of the Office of Rail & Road.

Related benefits

- Improved data led information to operational employees.
- Improved automation and integration of operational systems.
- Remove the risks associated with human error.
- Ability to keep trains moving, even during abnormal working or incidents.
- Improved systems to better manage movement on the railway during engineering work.
- Improved systems to better manage isolated electrical systems.

Scope

In order to address some of the operational risks associated with the railway network the following research and development may be required:

- Development of new or existing technologies to identify the exact location of trains in relation to railway infrastructure such as User Worked Crossings.
- Development of technologies to prevent trains being signalled into sections of the railway that are protecting workforce, work activities or isolated electrical section.
- Development of technologies to better integrate operational systems to provide a consistent interface with the user.
- Development of systems that identify the position and status of infrastructure during failures of first line systems such as train detection, points or signalling.
- Development of systems to better manage the risks associated with stopping a train safely when there has been an incident at the platform train interface during dispatch.
- Development of a tool to effectively assess the workload of operational employees and the potential impact of changes to work locations or practices.
- Development of common communication systems for all parties involved in safety critical communications and a single interface to allow voice communications to be retrieved

All the solutions developed for the operational railway shall be compatible with multiple operational systems and locations and are future proofed to align with the Digital Railway products.

fig. 1 - Collision & Derailment – Logan, Ayreshire, August 2015

fig. 2 - Example of VDU signalling centre

fig. 3 - Collision at Hockram Road User Worked Crossing, Norfolk, April 2016

Rail Running Surface Inspection

What is the situation?

Eddy current inspection has been introduced to assess the presence and severity of rolling contact fatigue (RCF) in rail to assist in rail treatments such as grinding or milling. Ultrasonic inspection remains the safety critical inspection method.

Eddy current inspection is well established testing method, but has not been used in the UK for rail maintenance inspection due to difficulties with data management and testing probe reliability.

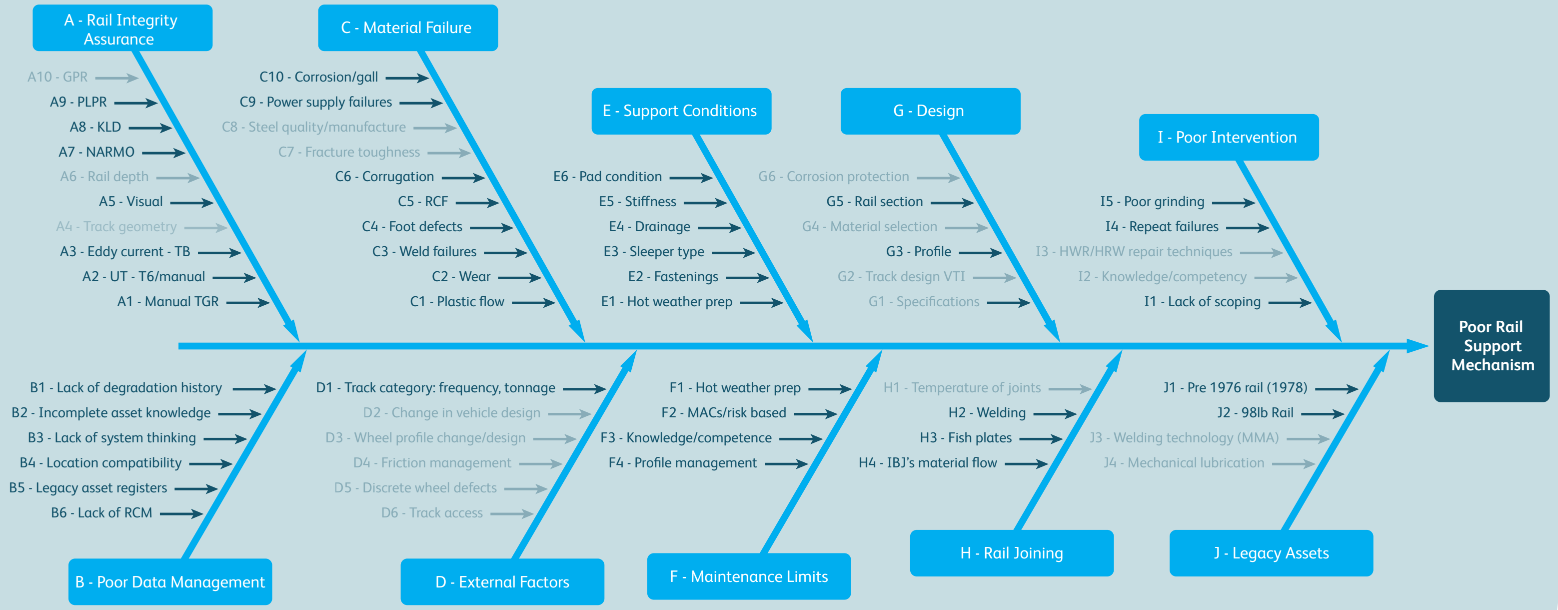
fig1.

fig2.

Network Rail's current supplier designed a probe array within a rubber wheel which is robust and operates at 30 mph when ultrasonic testing. Data is captured and post-test analysed providing a report for the deepest crack at a resolution of every 1m.

Large amounts of data and correction for positional errors common to trainborne inspection is challenging, with work ongoing to improve repeatability and reliability of data.

Analysis of causes



Priority problems

Specific priority problems	Related goal	Benefit
• No access available. • Improved detection. • Data amalgamation.	• Remove people from track. • Reduced broken rails and improved safety. • Earlier warning of track defect. • Improved defect knowledge. • Holistic risk control.	• Improved workforce safety. • Industry regulation measures. • Less disruptive planning. • Asset life extension. • Safety improvement.

Scope

There is greater demand to run trains which reduces opportunities to maintain and inspect the track. Traditional methods of inspection cannot be achieved due to access restrictions therefore semi-automated trainborne visual inspection systems are being used to replace manual patrolling.

Early detection of defects is desired to facilitate cost effective removal by grinding, milling or provide enough warning to plan for a possession to re-rail. Therefore improvements to the current processes would be a welcome step forward.

Obtaining reliable degradation information for defects is dependent on locational accuracy (sub 1 metre) and the repeatability of the inspection system. Using a contact system at speed is challenging particularly when reliability and repeatability is important.

Surface crack measurement systems generate many reports and defect management tools are needed to manipulate data and provide run on run degradation data, but combining this other data technologies would provide improvement. Projects such as the Intelligent infrastructure programme are helping deliver the digital railway is considering this.

Specific research needs

To address these challenges further research and development will need to consider the following factors:

- Understand the detection criteria and risk associated with each defect type.
- Trainborne location system to provide absolute position run on run.
- Inspection system to identify surface breaking defects accurately and repeatable.
- Able to operate in all weather conditions.
- Inspect track reliably at a minimum of 60 mph.
- Understand the assurance requirements and provide auditable records of inspection.
- Consider or provide a method to amalgamate other testing data into analysis to improve detection performance.
- System to manage defect population from inspection programme, compliance, detection and removal.
- Fully automated analysis of inspection using algorithms / neural networks.
- System to identify features – welds, work hardening, material changes, etc.

Expected impact & benefits

Improved defect detection and management performance:

- Earlier warning for maintenance and repair leading to less disruption to the customer.
- Improved safety and reduced risk.
- Reliable data turned into useful information – delivering predict & prevent maintenance.

Combined data analysis:

- Improved detection capability.
- Localised risk mitigation possibilities for defect management.
- Rail life prediction and risk modelling possible with database/tools.

Rail life extension:

- Improved rail treatment based upon improved data.
- Possibilities of identifying RCF before cracks occur?

V4 Reducing the number of Trespass Incidents & their impact on the railway

NetworkRail

What is the situation?

Trespass on the rail network is a key generator of both primary and reactionary lost minutes which negatively impacts upon railway operations. In 2018/19, the total performance delay costs associated with trespass and vandalism amounted to £55m.

What is the challenge?

Reducing anti-social behaviour which affects railway operations and causes delayed minutes and associated costs.

Detailed disruption data indicates that:

- Trespass disruption has increased significantly for the last 6 years
- Trespass disruption accounts for 42.4% of the total lost minutes for all disruption categories

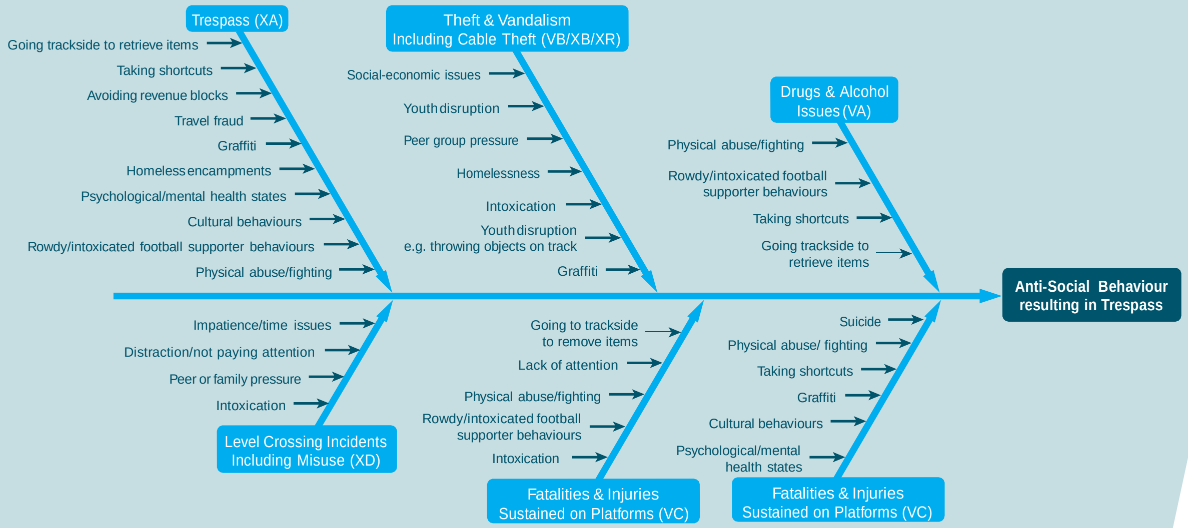
Example trespass hotspot locations only.
Data from 2017-19.

Why is it a challenge?

There are 13,500 incidents on the railway each year, affecting over 400 trains each day. There are various factors influencing why people trespass – please see the details in the analysis of cases section below. It should be noted that 70% of the XA trespass occurs within 100 metres of a train station. There are several measures to combat trespass but relatively few are new. Some fresh thinking is therefore required. Trespass incidents have increased over the last 5 years, as shown in the hot spot map. The challenge is to address the causes of disruption, minimising the effects on the railway operations and to obtain a lasting improvement using innovative and technological improvements.

Incident reason code	Title	Disruption per year (av 2011 - 2016)
VA	Disorder/drunks or trespass	144,176 lost mins
VB	Vandalism or theft	274,435 lost mins
XR	Cable vandalism or theft	132,190 mins
XB	Vandalism or theft (including the placing of objects on the line)	110,491 mins
VC	Fatalities or injuries sustained on platform result of struck by train or falling from a train	23,140 lost mins
XA	Trespass	380,861 lost mins
XC	Fatalities or injuries caused by being hit by train	426,427 lost mins
XD	Level Crossing Incidents including misuse	61,378 lost mins

Analysis of causes



Priority problems

Specific priority problems

- Rail passengers are committing trespass to evade ticket blockades.
- Groups of youths are committing trespass offences in the spring/summer at high impact disruption locations in line with Bank and school holidays.
- Trespass-related disruption events include suicidal trespassers or failed suicide attempts.
- Alcohol and travel fraud are significant contributing factors towards railway disruption.
- Identifying the exact location and details of a trespass can be problematic. Clear location and causal data is often hard to ascertain due to quality and delays in submitting reports.

Related goals

- Saving lives and maintaining the wellbeing of social systems which are disrupted when lives are lost.
- Improving the safety of railway operations.
- Addressing causal issues of anti-social behaviour which have wider negative social effects than the efficient running of the railway system.
- Improvement in reporting allows for better data analysis and improvement in identifications of related crime trends.

Benefits

- Cost savings to the taxpayer via minimising delay compensation costs.
- Performance benefits due to reduced trespass delay minutes.
- Improved passenger satisfaction.
- Safety and wellbeing benefit for public, passenger and railway workers.
- Improved social stability due to reduction in anti-social behaviour.
- Improving Network Rail's reputation as a responsible and caring business.

Specific research needs

To address these challenges, and gain the associated benefits, it is expected that R&D actions will need to address the following aspects:

- Existing or newly developed technologies (e.g. trembler alarms and motion-activated cameras) could be utilised to target specific hot spot trespass locations.
- Improvements in technologies with particular emphasis on solutions for Hot Spots and station platform ends.
- Developing solutions to address trespass that occurs along the lineside or in remote areas such as footpaths crossing the railway.
- Developing technology solutions which effectively prevent anti-social behaviour or its effects.

There is an important need to not only tailor solutions to problems at a local level but for those solutions to be future proofed and sustainable.

fig. 1 Level crossing misuse.

fig. 2 Graffiti.

fig. 3 Drugs and alcohol issues.

fig. 4 Suicide intervention.

Ultrasonic Rail Inspection

What is the situation?

Ultrasonic inspection can be split into manual and train borne testing which is carried out by an ultrasonic test unit (UTU). The UK rail network is inspected using a combination of both capture methods at inspection frequencies driven by track category. As with all methods of Non-destructive testing (NDT), cracks can only be detected when they are a certain detectable size. Testing therefore has to occur between the point of crack detectability and before the point of failure. It is therefore important to understand the capability (sensitivity and reliability) of the testing system and the propagation rates of rail defects to set testing frequency and defect removal time frames.

The introduction of semi-automated train borne inspection (UTU) has enabled NR to manage track defects far more effectively and has had outstanding performance results both safety and operationally. UTU's inspect around 64,000 miles of track using 4 trains over 750 shifts annually.

Increased capacity and demand from our customers is presenting significant challenges, as limited access needed to inspect and repair defects necessitates engineers to provide as much warning as possible to plan work. The challenge is for ultrasonic inspection to detect defects earlier enough to allow planned removal and prevent speed restrictions.

Rail breaks are now <10 % of the numbers experienced at the time of Hatfield (2000) where the trend has plateaued and improvements will be more easily achieved focusing on areas where ultrasonic inspection interacts with such as complementary data sources, databases and user tools.

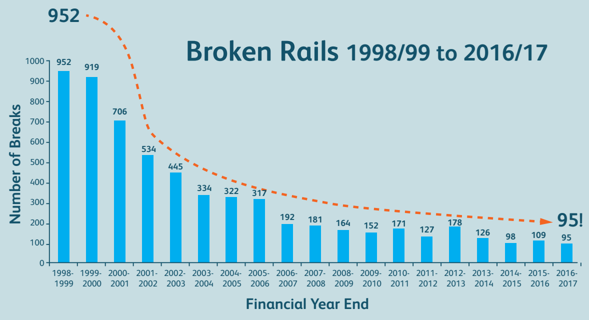


fig1. In 2016/17 we had 95, the best ever! This represents a reduction of 90% in 15 years. This reduction is against an average 50% increase in traffic over the same period.

Analysis of causes

Priority problems

Specific priority problems	Related goal	Benefit
• No access available. • Improved detection. • Data amalgamation.	• Faster testing speed. • Reduced broken rails and improved safety. • Less manual verification. • Earlier warning of rail defect. • Improved defect knowledge. • Holistic risk control.	• Access to timetable. • Industry regulation measures. • People off track. • Less disruptive planning. • Asset life extension. • Safety improvement.

NetworkRail

Scope

There is greater demand to run trains which reduces opportunities to maintain and inspect the track. Traditional methods of inspection cannot deliver the testing sensitivity alone or the ultrasonic test trains inspect at the speeds needed to blend in with normal train operations.

A number of initiatives to improve current testing speed capability (30mph) have been undertaken but there is always a trade off against detection performance. A small increase in speed will not permit running within the timetable, therefore significant speed increases are desired.

Early detection of defects is also desired to facilitate cost effective removal or provide enough warning to plan for a possession. Ultrasonic pulse-echo testing technology along with B scan analysis is well understood and the industry is seeking to expand the use of this technology further to improve data records and assurance. However, ultrasonic inspection alone cannot provide the detection sensitivity desired, but combining other technologies can provide improvements. Projects such as the Intelligent infrastructure programme are helping deliver the digital railway is considering this.

Vertical longitudinal split detection walking stick capability and manual B-scan are currently being explored with suppliers along with a vision to accommodate S&C inspection and placing VT, ET & UT on a trolley.

Specific research needs

To address these challenges further research and development will need to consider the following factors:

- Understand the detection criteria and risk associated with each defect type.
- Inspect plain line CWR track reliably at a minimum of 60 mph.
- Understand the assurance requirements and provide auditable records of inspection.
- Consider or provide a method to amalgamate other testing data into analysis to improve detection performance.
- Provide manual inspection systems delivering the same outputs.
- System to manage defect population from inspection programme, compliance, detection and removal.
- Methods to inspect track with no need for manual verification.
- Fully automated analysis of inspection using algorithms / neural networks.
- System to detect transverse foot cracks reliably at high speed.

Expected impact & benefits

Faster UTU:

- Better access for ultrasonic test trains within the timetable resulting in less possession disruption.
- More inspection undertaken in 1 shift possible 20 % saving on operations budget.
- Deliver greater testing capacity without the need for more trains.

Improved defect detection performance:

- Earlier warning for maintenance and repair leading to less disruption to the customer.
- Improved safety and reduce broken rails.
- Reliable data turned into useful information – delivering predict & prevent maintenance.

Combined data analysis:

- Improved detection capability.
- Localised risk mitigation possibilities for defect management.
- Rail life prediction and risk modelling possible with database/tools.

Unknown Asset Usage & Condition

What is the situation?

For successful asset management, access to accurate asset usage and condition information is critical. Unknown asset usage and condition introduces risk of inefficient asset usage, unpredicted breakdowns and ineffective planning of maintenance, overhauls and introduction of new assets.

Detailed usage of the asset is difficult to quantify as it is dependent on several factors, such as operating environment and intensity of work delivered. Most of the Network Rail engineering train fleets do not have technological capability to feedback how onerous or simple a shift was. The current level of usage monitoring for some fleets is recording mileage and worked distance. But if achieved in detail can provide a record of key performance indicator achievements from which long-term plans and contractual frameworks can be developed. It would also provide an indication of the assets condition.

Condition of the asset is an important part of the full asset life cycle and provides a tool for proactive action in saving costs and delivering high performance. This is currently achieved through manual inspections within the maintenance plans of the asset. However, there is opportunity to improve the efficiency of condition monitoring through technology developments and process improvements.

fig1.

Operating an asset without knowing a certain level of usage and condition increases the possibility of safety incidents occurring. This can often occur when trying to meet operational targets where the asset can be utilised close to its limitation without calculated information, risking the chance of in-service breakdown. Hence, to improve the assets safety profile in becomes critical to adopt progressive steps in detailing the knowledge of usage and condition.

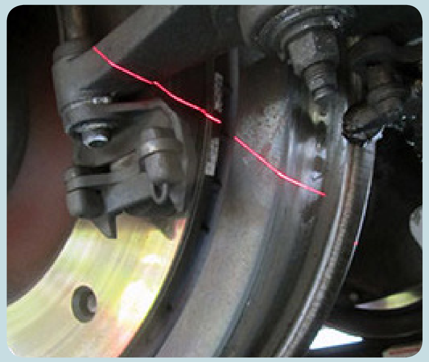
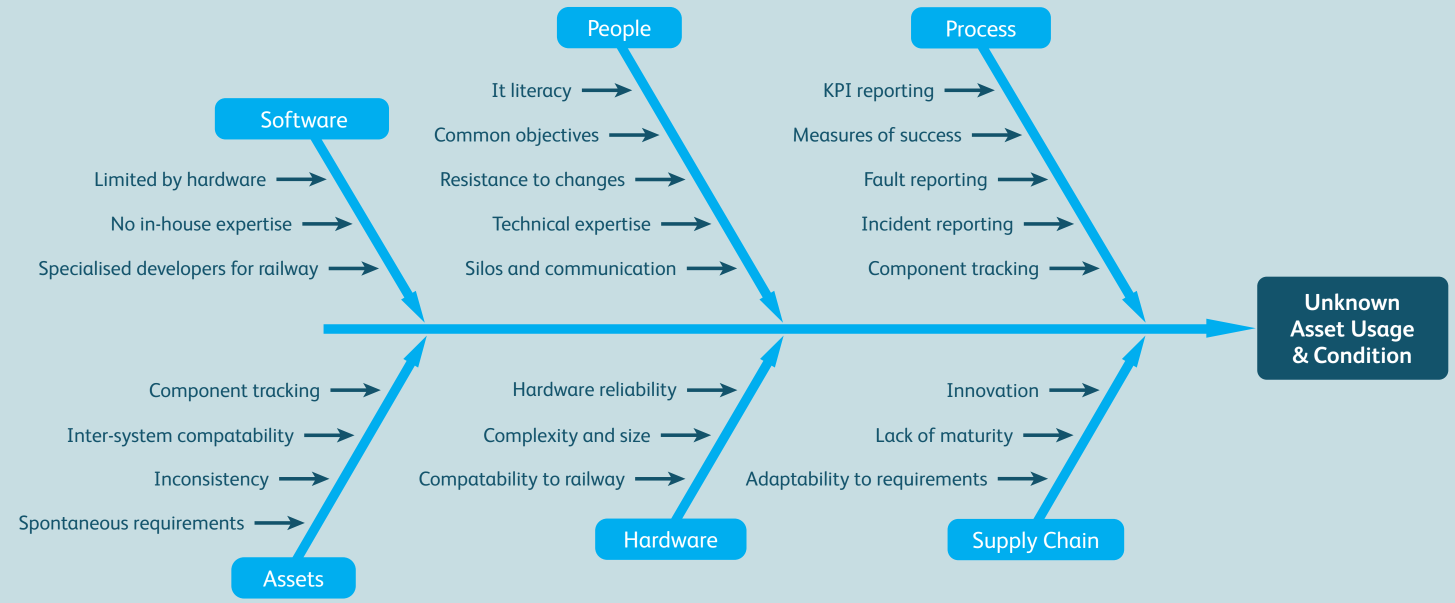


fig2.

Analysis of causes



Scope

The overall scope of the challenge is to investigate the potential for new technologies and techniques to monitor asset usage and condition.

Additionally, adopt and implement effective asset strategies to enable monitoring of usage and condition, such as deterioration curves to quantify the condition, identify pain areas and action to gain productivity of the asset.

Determine the relationship between condition of the asset to the usage requirements to make informed decisions of utilising the assets to full potential but within safety limits.

Provide adequate training and tools to people working the assets to enable informed decision making.

Priority problems

Specific priority problems	Related goal	Benefit
• Knowing the asset usage and condition to determine the necessary and cost-effective interventions to achieve the predetermined and desired service level and lifetime.	• Improving and utilising the use of current technology and techniques for determining and managing asset usage and condition.	• Return on investment of asset through product life cycle.
• Unknown asset usage and condition - understanding from a cultural point of view why it is important.	• Bring about accepted enhancements, which will ensure productive future use of technology, techniques or changes implemented.	• A technology enabled future allowing for smarter asset management.
• Diversity of the fleets (from age to deliverables) make single solution development difficult.	• Bring about uniformity of systems to implement joint progress across fleet. For example, compatibility of data sets.	• Sustainable use of resource and funds resulting in cost savings.

Specific research needs

- Determination of current techniques to record and predict asset usage.
- Single system for multipurpose condition monitoring.
- Productive use of a single data repository containing; asset specification, usage, condition, maintenance, repairs and failures.
- Understanding current position of asset usage and condition – How much is really known? Can improvements be made and why would they be necessary? When is data too much or not enough?
- Determination of comprise between what can be monitored, what needs to be known and feasibility of what is to be monitored.
- Uniform platform and benchmarks for diverse fleet.
- Adaptability of strategies.

Expected impact & benefits

- Be able to make informed decisions based on analysed and calculated trends.
- More efficient utilization of the assets.
- Better long- and short-term planning of asset investment.
- Improved safety of the asset.

Visual Track Inspection

What is the situation?

Visual inspection is the underpinning inspection method used throughout all industries. As the railway becomes increasingly busy with the requirement to improve safety it has been policy to separate workforce from trains. This has led to increasing volumes of work being undertaken under possession and at night.

Programmes to automate visual inspection using train mounted video cameras aligned with location and geometry (PLPR – Plain Line Pattern Recognition) have started to replace track patrolling. Asset Information Services (AIS) manages the capture, analysis and reporting which is delivered to the routes. An annual programme of around 950 shifts utilising 5 trains delivers a 4-weekly cycle of inspections.

Undertaking visual inspection at night significantly reduces the ability of the inspector to see defects due to poor illumination and shadowing cast by lamps when compared to natural day light. Therefore, the risk of missing defects must be understood and managed.

Analysis of causes

Priority problems

Specific priority problems

- No access available.
- Improved detection.
- Data amalgamation.

Related goal

- Remove people from track.
- Reduced broken rails and improved safety.
- Earlier warning of track defect.
- Improved defect knowledge.
- Holistic risk control.

Benefit

- Improved workforce safety.
- Industry regulation measures.
- Less disruptive planning.
- Asset life extension.
- Safety improvement.

NetworkRail

Scope

There is greater demand to run trains which reduces opportunities to maintain and inspect the track. Traditional methods of inspection cannot be achieved due to access restrictions therefore semi-automated train borne visual inspection systems are being used to replace manual patrolling.

Early detection of defects is desired to facilitate cost effective removal or provide enough warning to plan for a possession. Therefore, any improvements of the current processes are a welcome step forward.

Inspection at night where the ambient light levels are low is challenging, personal lighting is necessary to illuminate the components under inspection. Fixed box lighting and flood lights are used to assist with the inspections, but these can also cause environmental problems with light pollution and impact on lineside neighbours.

Automated visual inspection alone can generate too many reports to achieve the detection sensitivity desired, but combining other technologies can provide improvement. Projects such as the Intelligent Infrastructure programme are helping deliver the digital railway is considering this.

Specific research needs

To address these challenges further research and development will need to consider the following factors:

- Understand the detection criteria and risk associated with each defect type.
- Develop a visual inspection system to identify defects and areas of risk.
- Able to operate in all weather conditions (except covered by snow).
- Inspect track reliably at a minimum of 100 mph.
- Understand the assurance requirements and provide auditable records of inspection.
- Consider or provide a method to amalgamate other testing data into analysis to improve detection performance.
- System to manage defect population from inspection programme, compliance, detection and removal.
- Fully automated analysis of inspection using algorithms / neural networks.
- System has absolute position and compare change run on run.
- Fixed plant lighting – zero light pollution low energy.

Expected impact & benefits

More track inspection by train:

- Less people on track.
- Improved assurance.

Improved defect detection performance:

- Earlier warning for maintenance and repair leading to less disruption to the customer.
- Improved safety and reduced risk.
- Reliable data turned into useful information – delivering predict & prevent maintenance.

Combined data analysis:

- Improved detection capability.
- Localised risk mitigation possibilities for defect management.
- Rail life prediction and risk modelling possible with database/tools.

Improved relationship with lineside neighbours:

- Reduced light pollution.
- Reduced carbon footprint.

Welding Process and Technology Development

What is the situation?

We are reliant on conventional welding processes for joining and repairing rail (Aluminothermic circa 1900, Arc welding circa 1950s, Flash butt welding 1980/90s). These processes have evolved and are limited in their application. The quality of these welds are operator dependent requiring a high level of individual skill to deliver consistent weld quality.

There have been some developments in the processes and automation of flash butt and arc welding. Induction welding is also currently being developed for Switches and Crossings. The implementation of these processes is inconsistent and the potential benefits of automation are not being fully realised.

R&D to develop increased automation and reliability of rail joining and the introduction of plant and equipment specifically designed for welding and repairing rail offers improved quality, reliability, consistency, safety (asset and individual) and sustainability.

Numbers to support

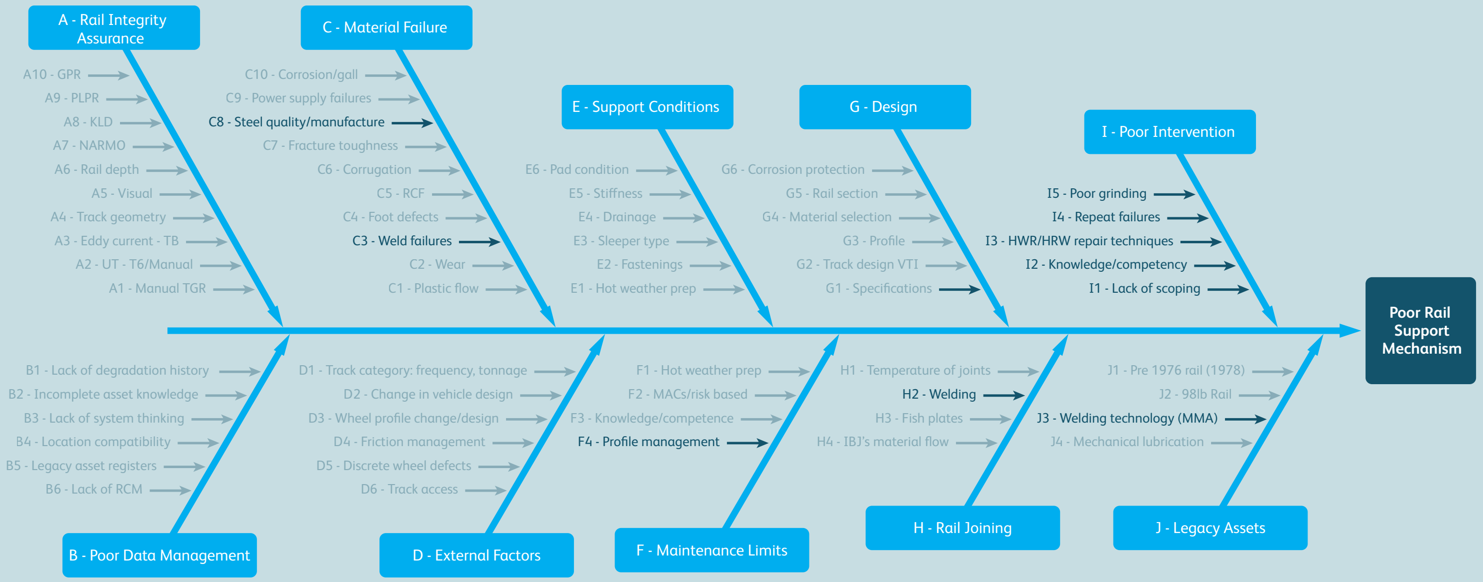
RDMS defect data on welds and rail defects – Rail welding and defect repair/removal generates a large workbank. Aluminothermic welds accounted for 30,000 maintenance welds and approximately 10-15,000 renewal welds in 16/17 with a national rejection rate of ~2.29 %.

Rail head repairs (Manual Metal Arc, Flux Cored Arc Welding and Automatic welding) accounted for 3,400 Plain Line Track defect repairs and 8591 Crossing defect repairs and 1636 switch defect repairs (of which 1530 are MMA).

Traceability of repairs that fail is not available from Network Rail databases. Based on Wales Route analysis a failure rate of ~15 % has been reported.

-700 NR welding staff, 38 competences, 3 NR welder training centres at York, Walsall and Bristol, 2 external training centres at InLine (Kent) and Babcock's (Scotland).

Analysis of causes



Priority problems

Specific priority problems

- Rail degrades in traffic necessitating replacement and repair of track.
- Replacement and repair of rails introduces defects requiring remediation.
- Automated welding technologies are limited.

Related goal

- To join and repair rails consistently so as to minimise the introduction of defects.
- To deliver consistent rail performance in traffic.
- Increased welding automation technologies.

Benefit

- Technology innovations facilitate improved rail management, safety, performance and reliability.
- Reducing reactive defect removal, risk and cost.
- Increased safety, quality, reliability and performance.

NetworkRail

Gap Analysis			Measure					
Cause	Countermeasure Name & description	Impact	0	20	40	60	80	100
H2, C3	**Aluminothermic process improvements**	• Developing single use crucibles for all NR approved rail steels and profiles to deliver increased weld consistency and reliability. • Development of the full suite of welding procedures for existing and new premium grade rail to facilitate use of premium rail steels. • Approvals of new manufacturing facilities to ensure continued supply of consumables (supplier relocating facilities). • Innovative Welding Processes for New Rail Infrastructures (WRIST) project outcomes have potential to automate some parts of the ATW process.						
J3, C3	**Introduction of arc welding within Mobile Maintenance Train**	MMT – delivering the capability to weld in a factory type environment delivering consistent and reliable welds on the asset: • Three phase generator, inverter and wire feed unit provision. • Compatibility of new equipment with existing approved equipment.						
J3, C3	**Arc welding three phase generation**	Three phase generation provides necessary power output in a single unit that can be coupled with inverters and wire fed units. Options include a tracked vehicle (transports generator and tools required in the four foot = 415kg total) carrying a single three phase generator or a modular generator capability (50kg/module machine) or a battery powered generator (under development). A Tracked option is used extensively in France and Italy where 5000+ cast crossings are welded per annum compared with 178 (15/16) & 141 (16/17) in UK using Network Rails automatic welding system (single phase power generation). Arc welding is currently dependent on single phase power generation, which necessitates sending two generators (115kgx2) to site to provide sufficient power OR over sized generators that introduce significant manual handling risks.						
J3	**Track circuit deposit work by fully automated system** *Zig zag welding that enables track circuits to work on little used PLT rail.*	This is labour intensive and an under utilised skill inconsistently applied. Two options to replace this are: 1. Current automatic technology available with wider application. Access and transportation issues are minimised as in PLT only. 2. Automatic system (used in Europe) using a tracked three phase power system (approval dependent) offers the potential to deliver reliable outputs and increased productivity **Note:** Continuous strip welding requires Signal and Telegragh approval.						
H2	**Induction welding modular S&C**	Existing welding techniques for modular S&C are limited to aluminothermic only due to space constraints between the S&C components. Aluminothermic welds take a minimum of 90 minutes to complete, whereas an induction weld takes a maximum of 45 minutes. This time saving facilitates welding operations during the core possession removing the need to clamp, impose a TSR and weld the following weekend. Cost and risk are significantly reduced by up to £750k @125MPH cross over. In 17/18 Infrastructure Projects (IP)renewals are replacing circa 200 sets of S&C. Induction welding process is potentially 100 % reliable. Safety considerations include reduced equipment weight (manual handling) and no high temperature and minimal gas emissions.						
C8	**Material development rail steels**	Continuous review and development of rail steels. Other European railways have ongoing work streams. Requires effective welding techniques to support installation, maintenance and repair (weld-ability).						
I5, F4, 14	**Automated portable datum grinder**	Semi automated grinding machine deliver consistent grinding outputs. Developments to move to a fully automated grinder capable of grinding a full profile using a laser measurement system offer continuous ergonomic improvement opportunities.						
F4, H2, I4, I5	**Modular switch grinder development**	A variation to the modular plain line grinder . This is currently in the design phase and requires a detailed specification. This would replace the existing Switch grinding units with a single type modular switch grinder improving ergonomic performance.						
C3, C8 H2	**Induction welding plain line**	Existing welding techniques for PLT are aluminothermic and flash butt welding. Aluminothermic welds take a minimum of 90 minutes to complete, whereas an induction/ Flash Butt weld takes a maximum of 30-45 minutes. Times include grinding. The cost of induction welding is potentially less than Mobile Flash Butt Welding and is potentially 100 % reliable. Safety considerations include reduced equipment weight and less risk in transportation/delivery of the working system. Environmental outputs are also reduced with no high temperature and minimal gas emissions.						
	Introduction of autonomous welding vehicles	Long term view to produce a fully automated vehicle that can operate on track, access to site, identify the defect, test, grind, weld, post grind, retest and move onto the next defect without human intervention.						
J3	**Induction rail pre heating system**	To replace the use of propane and propane rail heaters with an induction preheating system using 3 phase generators (with additional transformers).						
H2, I1, I2, I3, I4, I5	**National Welding Database**	There is a need to introduce a new National Welding Database that can allow all internal and external welding staff and welding companies/suppliers, management and engineers to input welds and weld inspections, create reports and conduct trend analysis etc. This needs to be accessed in real time and via site as well as desktops.						

Access, Set Up, Pack Up & Possessions

What is the situation?

The aim of a possession is to provide a safe, traffic-free worksite for maintenance activities to be carried out; such as remedial works, inspections, routine maintenance and planned renewals. Planning a possession requires early booking and is a significant coordination task, which at a high level requires consideration of the possession location and limits, access points, required duration and safe systems of work.

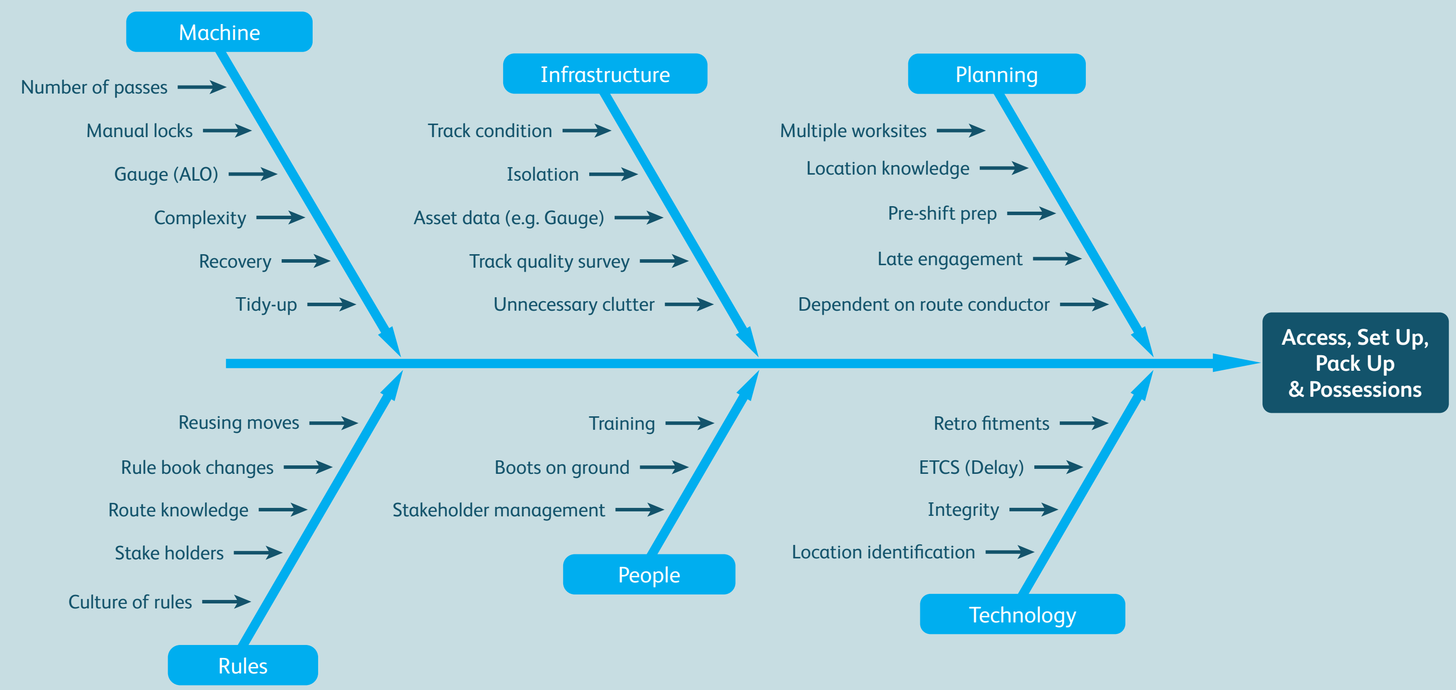
Possessions for engineering trains allow them to complete complicated maintenance which may require multiple passes and combined work with other engineering trains. Maintenance staff can also get off the machine for inspection or manual tasks. But with increasing traffic and reducing availability of possessions, being effective and efficient in accessing, setting up and packing up is vital not only to reducing the maintenance costs, but also to ensure work is completed safely and traffic is not delayed.

Possessions result in planned disruption which is difficult to manage but can also result in unplanned disruption which is very problematic. Delays from engineering trains is one of the biggest causes of delay minutes. Unplanned disruption can occur due to many reasons; machine faults, access issues, staff planning, wrong engineering train arrangement all of which demonstrates the complexity of planning possessions and likelihood of success.

Getting staff and equipment to the worksite on time and effectively and minimising the travelling distance are critical requirements for an efficient engineering access. The restrictions to this are mutual points for road and rail, number of staff and the type of equipment. Engineering trains usually start in sidings which can be in remote locations due to available sidings being occupied during large possession works. This makes timetabling and planning difficult to ensure the engineering trains reach the worksite at the correct time and in the correct formation.

Engineering trains also require significant set up and pack up time when they reach the worksite, leading to inefficient use of infrastructure capacity. For some engineering trains this is a very involved task requiring several staff and procedures. Preparation work also needs to be done at the site to dig ballast, mark cabling, isolation etc. which further requires infrastructure capacity.

Analysis of causes



Scope

The overall scope of the challenge is to optimise Access, Set Up, Pack Up & Possessions.

Although some improvements have been made in the problem areas identified they have been restricted to newer engineering trains and have not had consideration to the problem in its entirety. There is a requirement to develop solutions to planning, procedures and design of engineering trains such that possession efficiency is increased or even the requirement for possessions is eliminated, delivering infrastructure maintenance work with minimal disruption and costs.

Priority problems

Specific priority problems	Related goal	Benefit
• Planning of engineering trains, access and possessions is a complicated and multifaceted task.	• Streamlined planning of engineering trains with flexibility to adapt to changing requirements.	• Completion of planned maintenance when intended, reducing disruption to traffic.
• Machines require significant intervention and time to set up and pack up. Manual track quality surveys post machine shifts required.	• Simple deployment of engineering trains and increased use of technology.	• More infrastructure maintenance time.
• More compatibility of engineering trains to operate on diverse infrastructure routes.	• Engineering trains being able to conduct maintenance work alongside running trains and on live AC/DC infrastructure.	• No infrastructure preparation work required saving infrastructure capacity.
• Staff required off the machine increasing requirement for safety processes and procedures increasing time in start-up and hand-back.	• No boots on the ground.	• Increased staff safety

Specific research needs

- Investigate the possibility to plan possession in different ways. Development of planning tools for engineering trains which consider multiple scenarios, location and the type of work to ensure minimal impact to infrastructure traffic and capacity.
- Develop a way to have a better overview and availability of the necessary resources. Investigate cause and effect in last-minute planning.
- Design and development of new generation engineering trains with automatic deployment, track surveying technology and no requirement for staff on infrastructure, increasing possibility of infrastructure maintenance work without possessions.
- Development of engineering trains with low failure probability and simple recovery procedures.
- Research better methods of contractual managing of engineering trains to reduce risk of non-availability or poor performance.

Expected impact & benefits

- Reduce possession related cost due to engineering trains.
- Effective planning methods for engineering trains.
- Reduce putting staff in high risk locations, increasing staff safety.
- Increase productivity of engineering trains within possessions.
- Increase efficiency of engineering access for engineering trains.

Extending the Life of an Existing Footbridge Asset for 10 Years Within an 8 Hour Working Period

What is the situation?

The railway industry as a whole has witnessed a continual rise in the number of passenger and freight services across the country. This increase in services has reduced the amount of time available to the network maintainer and owner to implement repairs and inspections on the variety of ageing assets on the network.

The current forecast for 2030 shows a 34 % increase in passenger traffic and a 40 % increase in freight traffic. This essentially means that the already reduced possessions will continue to become even smaller and more pressured in order to complete necessary work on the infrastructure.

fig. 1

At present the assets within the buildings and architecture team are gradually ageing and as they age they will require complex, expensive and time consuming remedial work to be undertaken, in order to revive the assets back to a serviceable state that will allow them to remain operational for years to come.

fig. 2

One of the main challenges is station footbridges; there is often a need to erect an alternative footbridge when the existing one is under repair, as the repairs usually take a long time for a variety of reasons. With a number of structures under deconstruction, the hidden critical elements are found to be in a poorer state than previous thought and therefore, the remediation that had been proposed is no longer fit for purpose.

With future possession demand set to become more constrained and more difficult to obtain, it is important that repair work can be completed in the shortest time frame as possible, giving an extended period of life back to the asset to allow it to function until the next remediation can take place.

fig. 3

Priority problems

Specific priority problems

- Insufficient access to maintain footbridges at an efficient rate to maintain serviceability and safety.
- Insufficient time to carry out the existing way of working.
- Existing repairs do not always give enough life expectancy back to the asset.
- Insufficient knowledge of condition pre work.

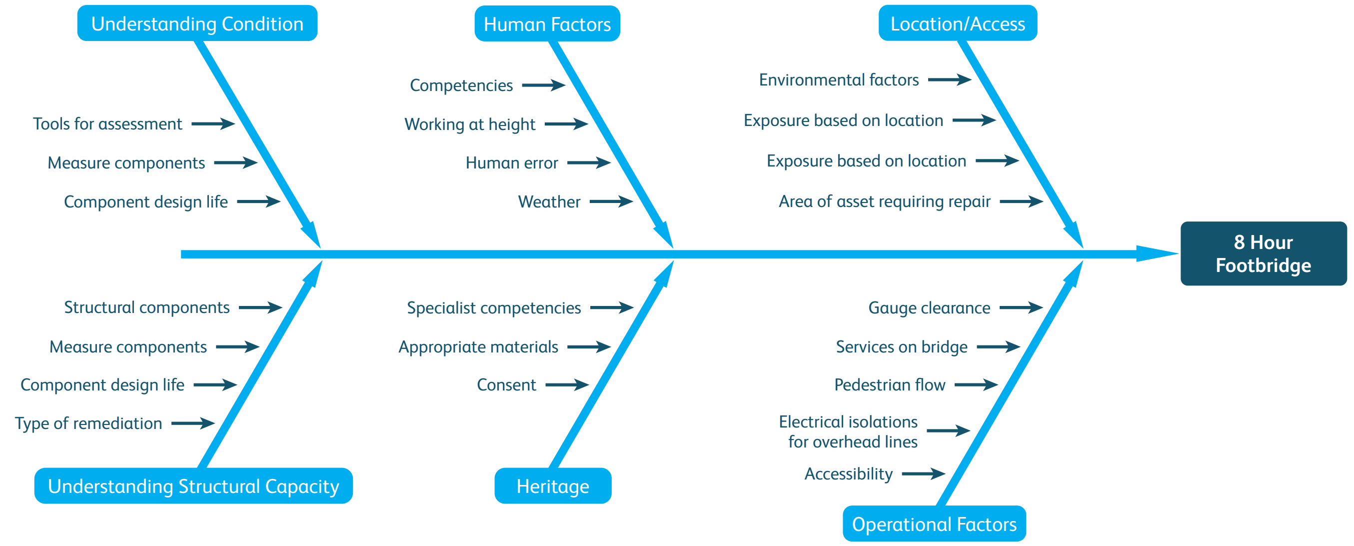
Related goals

- Reduce the amount of time taken to remediate a footbridge.
- Extend the life of an asset whilst keeping the cost of the remediation as low as possible.
- Minimise the amount of work required by patch repairs.

Benefits

- Reduce the amount of time needed to remediate the assets.
- Reduction in cost of possession time.
- Reduction in cost of compensation for taking control of lines for an extended time.
- Reduction in cost of alternative measures for bridge remediation.
- Increase the sustainability of the assets by increasing their condition scores.

Analysis of causes



Scope

Explore how existing projects are done for a footbridge extension of life by 10 years, and process how this can be reduced to meet the 8 hour target working time.

Any techniques of remediation may be used to achieve this goal of 8 hours; however it can be no more than this, and must extend the life of the footbridge for 10 years. Thus, ensuring the remediation adds a sufficient amount of design life back to the asset and ensures no extra work is needed in the near future.

The remediation may differ for different bridges however; the set-up on site, planning and all the methods used must fit into an 8 hour window for any bridge design.

Specific research needs

To address these challenges it is expected that R&D actions will need to address the following aspects:

- What remediation will need to be made in order to extend the life of the asset by 10 years?
- How can a footbridge asset be remediated in 8 hours?
- To create a tool, process and mechanism that will be able to come in and whatever the remediation, it will be able to do the remediation that is needed, whilst keeping to within the 8 hour time window whilst also giving 10 years to the extended life of the bridge.
- There will be a need for the assessment tool to be easy for engineers to interface with and work with to get the correct solution as easy as possible whilst on site. There will be a need for the tool, processes and mechanism to be flexible and deploy for the wide range of different scopes and problems.