Report on Common Problems Faced by Rail Infrastructure Managers

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## DOCUMENT HISTORY

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1 Executive Summary

This report presents examples of typical failures of infrastructure on rail networks. Examples from Destination Rail partners and from other networks are included to identify the key challenges facing infrastructure managers. Consideration is given to how changes in use (increased speed and or loading) and climate change might affect the performance of infrastructure and cause increased incidence of failure. The purpose of this report is to ensure that the relevant issues are covered in a robust manner in the Destination Rail project. The database of problems collated as result of workshops held between Destination Rail partners is now available on the Destination Rail website (www.destinationrail.eu).
2 Introduction

The establishment of a Single European Railway Area (SERA) is seen as being critical to ensuring long-term competitiveness, dealing with growth, fuel security and decarbonisation in the European Union. One of the obstacles to achieving this is the very large number of high profile failures of rail infrastructure that have occurred in recent years, with the incidence appearing to increase in response to climate challenges and aging networks amongst other factors. Work Package 1 (Find) in the Destination Rail project addresses advanced visual assessment and structural health monitoring (SHM) to determine the real-time condition of infrastructure assets. A key part of this work is the development of algorithms to help find ‘Hot-Spots’ (critical sections of the rail infrastructure) rather than classifying these after an event.

The Work Package is divided into five sub-tasks. The first task involved compiling a database of key infrastructure problems faced by Railway Infrastructure Managers IM’s. Workshops were held between researchers, SME’s and IM’s and a list of problems affecting infrastructure objects including; slopes, tracks, bridges, switches and crossings, sea defences, tunnels and retaining walls has been compiled. In this report examples of typical failures are presented. In the final section consideration is given to how changes in use (increased speed and or loading) and climate change might affect the performance of infrastructure and cause increased incidence of existing or new or heretofore unseen problems. This will ensure that the relevant issues are covered in a robust manner in the Destination Rail project. The database of problems is now available on the Destination Rail website (www.destinationrail.eu).
3 Typical Failures

In this section examples of typical failures that effect European rail infrastructure are presented.

3.1 Slopes

Common problems affecting slopes are shallow translational landslides caused by high rainfall, settlement due to weak sub-layers, rock falls caused by freeze-thaw effects and deep-seated rotational failures caused by weak sub-soils which are triggered by increased loading and/or changes in the water table.

3.1.1 Shallow Translational Failures

Many slopes along railway networks were built more than 100 years ago at a time before modern design standards were developed. As a result the average slope angle of these assets is much higher than would typically be permitted for modern transport infrastructure. The role of near surface suctions in providing stability to these slopes is understood (See Fourie et al 1999). However, this aspect of stability is temporal as near surface suction reduce during rainfall or flooding events (Gavin and Xue 2009). As a result shallow translational landslides typically occur after periods of high rainfall. An example of shallow landslides on the Slovenian and Croatian rail lines are shown in Figure 1a and 1b respectively. Both occurred near the entrance to tunnels where slope angles are usually at their highest.

Figure 1 a) Shallow Landslide on line between Ljubljana-Kamnik, Slovenia, b) Failure at the Tunnel Zaluka on the railway line between Karlovac-Kamanje.

Because of the relatively small volume of soil involved the consequence of shallow translational slides that are confined to rail assets (cuttings or embankments) and
occur when the track is above the failure are usually low and depend very much on the clearance between the slope edge and the track. In contrast when failures occur in slopes above the track, the soil mass can cover the rail track and cause derailments, and in rare cases the failed mass might impact a passing train. Another source of enhanced risk occurs when the failure happens in natural hill sides above the track and a debris flow develops. An example from the Slovenia rail network (the track is visible near the bottom of the photograph) is shown in Figure 2.

![Figure 2](image)

**Figure 2**  Debris flow in the mountains on the rail line Bohinj-Nova Gorica, Slovenia

### 3.1.2 Deep rotational failure

Deep rotational slope failures typically involve large volumes of material and occur in new construction because of weak sub-soil and on older assets when some change in the boundary conditions occur. A major slope failure occurred on the 11th of February 2013, near Hatfield Colliery, in South Yorkshire in the United Kingdom. The landslide resulted in major deformation to the rail track, See Figure 3a. The movements were caused by progressive failure triggered by instability in the nearby waste heap, See Figure 3b. The railway slope suffered a large rotational landslip, See Figure 3c and the track repairs took six months to complete.
3.1.3 Rock falls

Rock falls occur primarily because of natural jointing in the rock mass. The failure mechanism can be accelerated due to freeze-thaw action and thus climate change will cause an increase in such events. There is a strong correlation between rock falls and intense rainfall and low temperature. An example of a recent rock fall on the Zaprešić-Čakovec line in Slovenia is shown in Figure 4.
3.1.4 Other Issues

A number of additional issues were highlighted as causing slope stability problems. These included the issue of poorly maintained or blocked drainage, which will allow for the eradication of near surface suctions. Another feature that is becoming an increasing management issue is animal burrowing. The burrow holes allow for rapid movement of water to relatively large depths in earthworks during rainfall or flood events. Many regions across Europe are susceptible to karst weathering. Solution features which can develop include caves and sink holes. When embankments are located near rivers or on flood plains, river scour can occur during periods of flooding, recent high impact examples from Slovenia are shown in Figure 5.
3.2 Tunnels

A number of common problems for tunnels were identified that included; flooding, drainage problems, seepage/ice formation, poor structural support and limited clearance.

3.2.1 Flooding

Heavy rainfall can cause flooding and temporary closure of tunnels. An example from the Isle of Wight, November 2010 is shown in Figure 6.

![Flooding at Ryde Esplanade tunnel, Isle of Wight (source Wikimedia commons)](image)

3.2.2 Drainage

The lack or poor levels of maintenance of tunnel drainage can cause a number of problems, including the development of Seepage/Ice Formation, (Figure 7) that can obstruct the tunnel. Poor drainage can cause the build-up of pore pressure on the tunnels structure leading to cracking and potential collapse.
3.2.3 Lack of Support/Clearance

Many old railway tunnels were of bored construction, unsupported through bedrock or with inadequate or degraded support through ground conditions consisting of interbedded soil and rock profiles. Maintaining adequate clearance through these assets is a major issue, See Figure 8. In many cases tunnel bores do not provide adequate clearance, particularly to allow electrification. The lack of adequate structural support limits the options for remedial solutions such as under-excavation or the introduction of ballastless tracks.
3.3 Tracks

3.3.1 Ballast Problems

Ballast degradation occurs as a result of high stress level cyclic loading and can be exacerbated by weathering. An example of ballast fouling or choking leading to a significant reduction in the porosity of the ballast layer in Slovenia is shown in Figure 9. Ballast spreading can occur due to poor specification of the material or due to weak subsoil.

![Figure 9](image)

**Figure 9**  Choked ballast and concrete sleepers, Slovenia

3.3.2 Track Problems

Extreme heat causes steel rail track to expand and buckle or kink, See Figure 10a. This can be a safety critical issue leading in many instances to derailments. Due to the cyclic nature of railway loading structural elements are subject to fatigue damage, an instance of fishplate shear from Slovenia is illustrated in Figure 10b.

![Figure 10](image)

**Figure 10**  (a) Lateral buckling of the track due to the high temperatures, Slovenia, (b) Breakage of fishplate due to the rail fatigue, Slovenia
Track *flooding* can cause a potential hazard as evidenced by the derailment of seven rail cars carrying coal in Vancouver on January 11\(^{th}\), 2014, see Figure 11.

**Figure 11**  Flooding of track can cause a hazard as evidenced by the derailment of seven rail cars carrying coal in Vancouver on January 11\(^{th}\), 2014

### 3.3.3 Weak Subsoil

Weak subsoil is usually evidenced by ongoing settlement issues, see Figure 12. Often these issues are dealt with by re-ballasting. However, ignoring the underlying mechanisms can result in large-scale slope stability failures as described by Donohue et al. (2011).

**Figure 12**  Settlement of embankment, Slovenia
3.4 Bridges

A number of issues related to bridge damage were noted, these included; Corrosion, Overloading, Scour, Accidental Impact, Issue with bearings, Cracking, Lack of transition zones and the collapse of arches in Masonry bridges.

3.4.1 Corrosion

Metallic bridges are susceptible to corrosion, which is a time-dependent process and results in a reduction of cross-section resulting in loss of stiffness and potential failure. An example of corrosion on the Boyne Bridge in Ireland (one of the Destination Rail demonstration projects) is seen in Figure 13.

Figure 13  Corrosion at connection between rail bearer and cross beam of Boyne Bridge

3.4.2 Overloading

Whilst over-loading is a common problem on road bridges, there is more control of vehicles on rail tracks and therefore overloading due to train weight is not common (Bell 2014). However, with increased track speeds dynamic loading factors should be considered.

3.4.3 Scour

Scour is the leading cause of bridge failure in the world (Prendergast et al 2013) and has led to the failure of many important rail bridges, including the collapse of the Malahide viaduct on the Ten-T network between Belfast and Dublin in August 2009 and severe damage to a rail bridge over the river Sava In Croatia in the same year. Scour is the removal of material from around the foundation of a river pier or abutment during periods of flooding. The removal of material causes a loss of
stiffness and can lead to collapse. Recent examples of scour and remedial works to improve the situation on the Slovenian network are shown in Figure 14.

![Figure 14 Scour of foundation at bridge Plaznica (line Ljubljana-Jesenice)](image)

### 3.4.4 Accidental Impact

Byrne (2009) reports on bridge strikes along the Irish Rail network. He notes that on average 180 railway bridges over roads are reported as being hit by oversized vehicles each year in the Republic of Ireland, see Figure 15.

![Figure 15 Underbridge strike, Custom House Quay, Dublin (image from Byrne 2009)](image)

An underbridge strike occurred on the Dublin to Rosslare Mainline near Gorey County Wexford in 1975. A truck carrying construction plant completely dislodged two wrought iron girders, leaving the track unsupported, see Figure 16. The strike occurred on New Year’s Eve just before the 8.05am Rosslare Harbour-Dublin train
arrived on the bridge at an estimated 60 mph. The bridge collapse resulted in five fatalities and thirty injuries.

![Image](image from Byrne 2009)

**Figure 16** Underbridge demolished near Gorey, Ireland (image from Byrne 2009)

### 3.4.5 Other Issues

Other issues of concern identified in the review were problems with *bearings*, *cracking* in concrete structures, the absence of *transition zones* causing poor ride quality and introducing large dynamic amplification at bridge abutments and poor (or missing) *foundations*, See Figure 17.

![Image](image from Byrne 2009)

**Figure 17** Settlements of bridge foundation caused cracks in masonry bridge in direction Borovnica-Verd, Slovenia


3.5 Retaining Walls

Whilst most modern retaining walls comprise thin structural elements embedded in the soil mass that mobilise the soil resistance to support external loads, given the age of the European railway network a large proportion of the retaining structures are gravity structures. These walls rely on self-weight of the structure and the retained soil, see Figure 18. Geotechnical checks that need to be considered to assess the wall stability include sliding resistance, overturning resistance and that the bearing resistance of the subsoil is adequate.

![Sketch of Gravity Retaining Structure](image)

Amongst the problems facing designers in their attempts to assess these failure modes is that the walls are large, not homogenous (e.g. they are constructed from discrete blocks) and it is not easy to assess the structural integrity or to determine the condition at the wall-soil interface (which is critical). They operate based on the assumptions that free draining material behind the wall or weep holes in the structure itself prevent the establishment of static water pressure at the rear of the wall. Therefore, the walls are sensitive to changes in the hydraulic regime and blocked drainage can lead rapidly to the development of pore pressures at the rear of the wall and precipitate failure. Because of the effects of ageing many of the structures have relatively low factors of safety, ageing degrades the structural capacity of the blocks and any mortar in joints can disintegrate or flow out. Given their low safety margins these structures are particularly sensitive to any change in loading. An example of a recent failure of a wall on the Croatian Rail network is shown in Figure 19. The train driver was fatally injured in this accident.
3.6 Switches and Crossings

Although not large-scale Civil Engineering infrastructure, issues related switches and crossings were raised during the workshops and included herein for completeness. The primary causes of failures were identified as failure due to ice, high temperatures affecting operation, cable removal by thieves, differential settlement due to poor tamping, lack of or poorly performing drainage and track geometry problems.

3.7 Sea Defences

Many of the old railway networks were built near the coastline. Coastal erosion can pose a significant challenge for infrastructure managers, see Figure 20.
Coastal flooding can cause scour of sea wall foundation and track bed. In February 2014 a coastal flood caused severe damage to a section of the mainline rail at Dawlish, in Devon, see Figure 21. The flood caused a 30m long stretch of the sea wall to collapse and resulted in severe scour of the rail track and damage to adjacent houses. This important section of track was remediated quickly, reopening two months later. The repair costs were estimated at 35 million pounds sterling.
4 Effect of Increased Loading and Climate Change

4.1 Background

The effects of climate change are being felt across Europe with the last decade being the warmest since records began. Precipitation rates are varying, becoming higher in Northern and North Western Europe, whilst decreasing elsewhere, and there are noticeable reductions in snow and ice and a trend towards climate extremes (IPCC, 2013). The European Environment Agency (EEA, 2014) report on adaptation of transport to climate change in Europe identified a number of climate pressures to be considered for rail infrastructure. These included; summer heat, winter cold/ice (see Figure 22), extreme precipitation and extreme storms. The report considered the risks associated with these pressures, the time frame over which impacts could be considered and the regions affected, see Table 1. The data has been updated to consider risks identified by Destination Rail partners. EEA (2014) note that the effect of these changes will be reduced safety, increased cost for maintenance and repairs and disruption to just in time delivery of goods and passengers.

Figure 22  Damage to overhead lines in Slovenia
Table 1  Climate risk and impacts on rail infrastructure (modified after EEA 2014)

<table>
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<th>Climatic Pressure</th>
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<th>Time Frame</th>
<th>Regions mainly affected</th>
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<td>Summer heat</td>
<td>Rail buckling, Material fatigue, Increased instability of embankments, Overheating of equipment, Increase in wildfires</td>
<td>Medium Negative (2025:2080) to high negative (2080)</td>
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<td>Winter Cold/Ice</td>
<td>Ice on trains and catenary, Rock falls (freeze thaw), Ice formation in tunnels</td>
<td>Medium negative (2025:2080)</td>
<td>Northern Europe, Central Europe</td>
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<tr>
<td>Extreme Precipitation</td>
<td>Damage on infrastructure due to flooding and/or landslides, Scour to structures, Destabilisation of embankment</td>
<td>Medium Negative (2025:2080) to high negative (2080)</td>
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<td>Extreme Storms</td>
<td>Damage to infrastructure such as signals, power cables etc. due to falling trees etc.</td>
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4.2 Implications for Rail Infrastructure

There are limited statistics available related to the effect of climate change on rail infrastructure. Where data is available (for example on the Dutch transport system; Koetse and Rietveld (2009) and Stipanovic Oslakovic et al. (2012) or in the United States; Rossetti (2002)) the data suggest relatively high failure rates which are related to the local climate, technological advancement of the operator and geographical factors (for example landslides in natural slopes are rare in the Netherlands). A complicating factor is the definition of failure; the Destination Rail project is concerned with safety critical incidence for major infrastructure elements
(e.g. a bridge or a tunnel) and only major failures which are threatening to life are considered.

**4.3 Destination Rail Approach**

The objective of the project is to provide Infrastructure Managers with best practice tools and methodologies for risk assessment of critical infrastructure elements, such as bridges, slopes, tunnels and tracks. The methodologies that will be developed within Work Package 2 of the project (Analyse) will provide the facility to optimise budgets/resources from the perspectives of minimisation of cost for maximised service life performance. The developed methodologies will also facilitate statistical updating of predicted performance on the basis of information received from both actual and virtual Structural Health Monitoring (SHM) installations and therefore feed to the decision support tool (WP3 - Classify) and LCA (WP4 - Treat).

A probabilistic framework will be developed to facilitate multi-criteria performance optimization of railway infrastructures (i.e. structures, earthworks and tracks). A probabilistic basis is ideal as it facilitates stochastic modelling of the governing variables concerned with railway infrastructure life cycle performance optimisation, e.g. loading and load evolution, resistance and resistance deterioration with time, the effects of climate and alternative intervention strategies etc. Significantly the development of a probabilistic basis also facilitates statistical updating of distributions of modelled variables where this becomes available through instrumentation or structural health monitoring.

The application of the algorithms developed for the assessment of performance of railway structures will be demonstrated through consideration of a case study bridge, the Boyne Viaduct in County Louth, Ireland. The multi-criteria performance optimization algorithms developed will be employed to study the implication of load evolution, deterioration and alternative rehabilitation strategies for this landmark structure.

Failure models for shallow translational failure (triggered by rainfall, earthquakes etc.), rotational failure (triggered by new construction, flooding etc.) and rock falls will be coded using an invariant reliability analysis technique.

The most important factors determining the capacity of tracks to handle excitation loading is track stiffness and damping factors. There is also a link between the track performance in terms of stiffness as well as track quality in terms of actual geometrical situation (rail alignment).

An integrated modelling system will allow the dynamic analysis of the train-runs along track sections including real track geometry and track stiffness. The output of the model will include both results related to train and track behaviour, like the displacement of the track, the wheel load distribution and the wheel-rail interaction force. The models will be used to study the design requirements for new track infrastructures for mixed train traffic.
5 Summary and Conclusions

The report summarises the findings from a series of workshops held with infrastructure managers to consider the most common problems that affect rail infrastructure across the EU. To ensure a broad European perspective the partners engaged with infrastructure managers and research outputs outside the project. Examples of typical problems are presented in this report and it is expected that these will inform the work of the project.

Having identified the most critical failure models consideration was given to potential effects from ageing, increased use, higher loading and climate change to the likely development of these problems. It is evident that the models developed within the Destination Rail project, specifically the reliability based capacity models and the decision support tool will provide a means for railway owners to quantify and manage risk along their networks.
6 References