Probabilistic approach to evaluate need for rail remediation using large data sets

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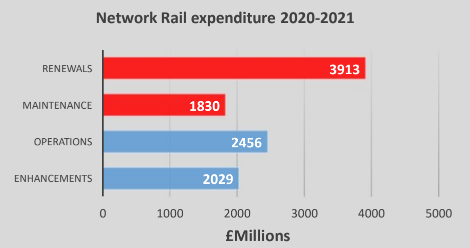
Introduction

Research questions:

1. Is railway track maintenance efficient?
2. Can current practice be updated to extend asset life and minimize whole lifecycle cost?
3. How can the rail industry contribute to decarbonisation?



Aim of research:

Big data analysis using machine learning algorithms for a better understanding of long-term behaviour of high-speed tracks.

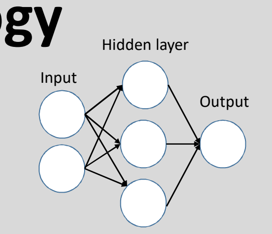
Research objectives:

1. Development and assessment of machine learning models.
2. Estimation of track maintenance efficiency.
3. Isolating and monitoring track fault development.
4. Determining root-causes for track faults.
5. Proposing new approach for targeted maintenance works.

Methodology

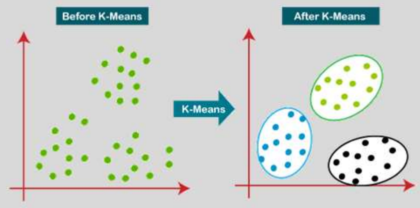
Supervised machine learning

- An Artificial Neural Network (ANN) has been applied for classifying discrete track segment based on geometry deterioration.
- Maintenance efficiency estimated based on results.



Unsupervised machine learning

- An Autoencoder has been used to highlight regions of track exhibiting change in quality.
- KMeans clustering algorithm used for determining if the region is exhibiting deterioration or has undergone maintenance.



Partners

Loram UK Ltd

- Primary funding partner and consultant
- Contact: Mr. Paul Long – Technical director

Network Rail High-Speed

- Data provider and consultant
- Contact: Mr. Matthew Rippin – Head of track engineering (High-Speed 1)

Loram Technologies Inc, Georgetown TX, USA

- Consultant
- Contact: Dr. Hamed F. Kashani – Manager of Railway geotechnics

University of Massachusetts, Amherst

- Consultant
- Contact: Prof Carlton L. Ho

Proposed research

Research environment

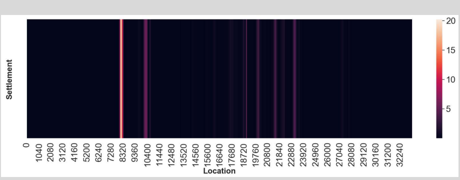
- Track quality is often expressed in terms of standard deviation (SD) from fixed 200m segments.
- Local fault developments cannot be detected using this method, resulting in lower maintenance efficiency.
- Maintenance reduces ballast bearing capacity over time, effectively shortening its lifespan.

Refined data analysis approach

- Quick processing of vast amounts of data to detect local fault development.
- Combination of different available data sets for a more complete understanding of track behaviour.

Model sensitivity calibration

- -0.1mm change in SD exhibits deterioration
- +0.3mm change in SD exhibits maintenance
- Calibration can be adjusted based on track quality and requirements.

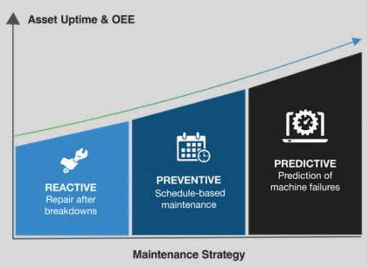


Model output exhibiting track settlement covering an 8km long span. Warmer colours show higher deterioration.

Outcomes

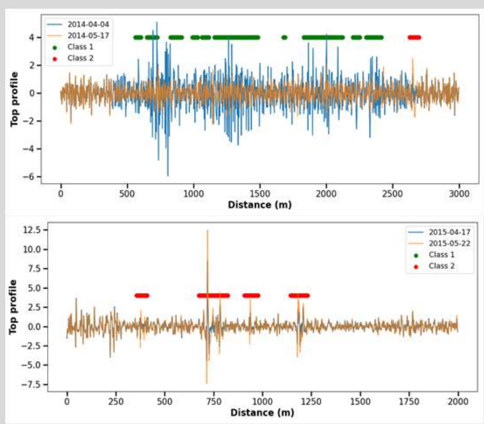
Deliverables:

1. **Improved track quality and passenger safety**
2. **Reduced tamping and associated costs**
3. **Better allocation of available resources**
4. Extended ballast life
5. Preventing damage to rolling stock



Impact on industry:

1. Isolating local defects and determining reasons for deterioration.
2. Understanding long-term track behaviour.
3. Refining and optimising maintenance scheduling techniques.
4. More stable and reliable infrastructure, promoting expansion and decarbonisation.



Examples of fault localization algorithms. Direct output from KMeans clustering analysis shown above.
Class 1 – maintenance; Class 2 – deterioration.

Maintenance efficiency

- It has been found that not all of the tamped track undergoes quality improvement.
- When the quality is already high prior to maintenance, the effect of the works is negligible.
- Large-scale works in particular were found to be more inefficient than local tamping.

Activity	Large-scale tamping	Local tamping	S&C tamping
Track with improved short-wave profile	30.1%	78.1%	34.5%
Track segments with improved twist (3m)	36.7%	67%	28.6%
Track with improved long wave profile faults	36.9%	55.7%	35.8%
Overall efficiency	52.5%	84%	45.6%

Value to the industry

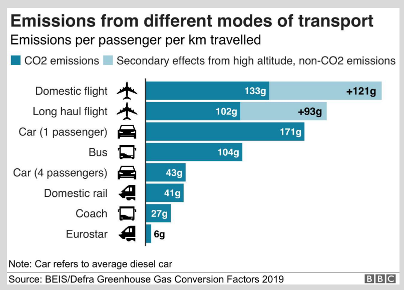
Current practice and challenges

- Rail operators rely on reactive and preventive methods of maintenance.
- Track is often tamped while it is in good condition.
- Critical faults lead to restrictions or line closures, causing train delays and financial penalties.
- Higher transportation demand moving forward will add more pressure to the available infrastructure.

Network Rail's New Measurement Train for inspecting track quality with high precision.

Innovation

- Constant monitoring of track to forecast failure times.
- Detecting rapid track settlement allows to investigate the root-cause of defects and eliminate them.
- Making railway journeys more reliable and attractive can expand the industry and help achieve more sustainable transportation.



Cost saving

- Local fault isolation helps prevent severe defects and allows more efficient maintenance allocation.
- Extending ballast life by reducing tamping will also reduce expensive renewal works.
- Potential annual maintenance cost reduction of 30%.

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