KTH ROYAL INSTITUTE
OF TECHNOLOGY

Verbesserte Unterhaltsplanung für Rad und Schiene mithilfe eines digitalen Zwillings

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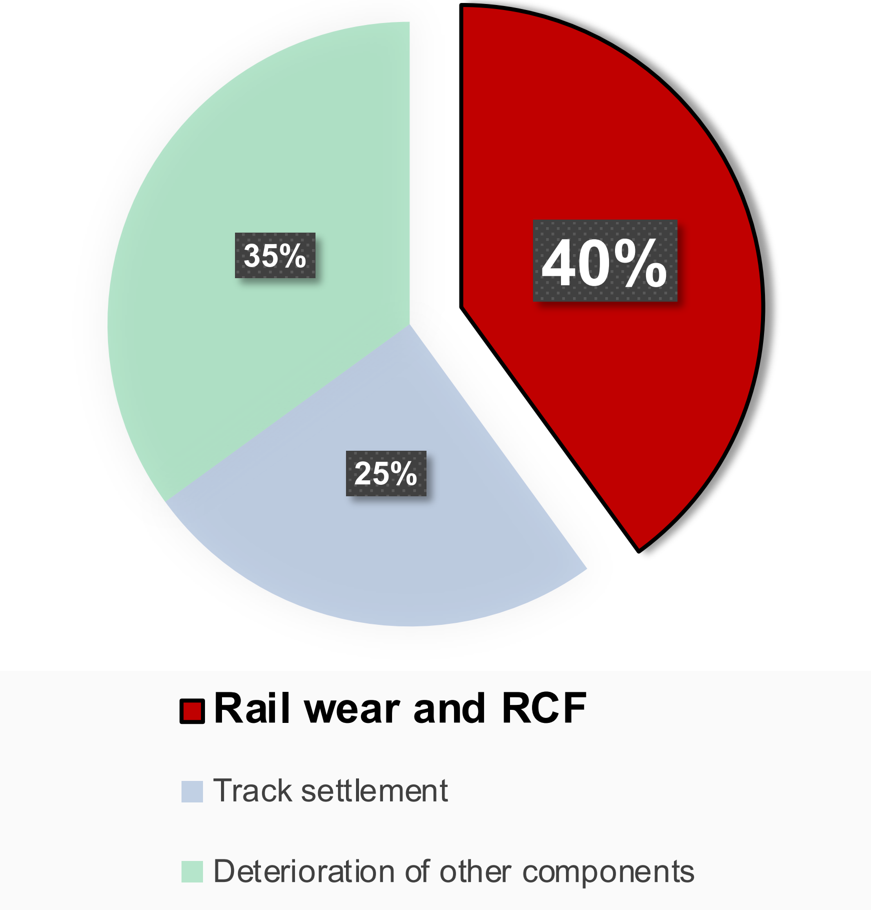
Outline

- Introduction
- Calculation of rail damage – Optimisation of grinding intervals
- Wheel life prediction – Planning of reprofiling intervals
- Machine learning tools to predict track irregularities or local defects
- Summary

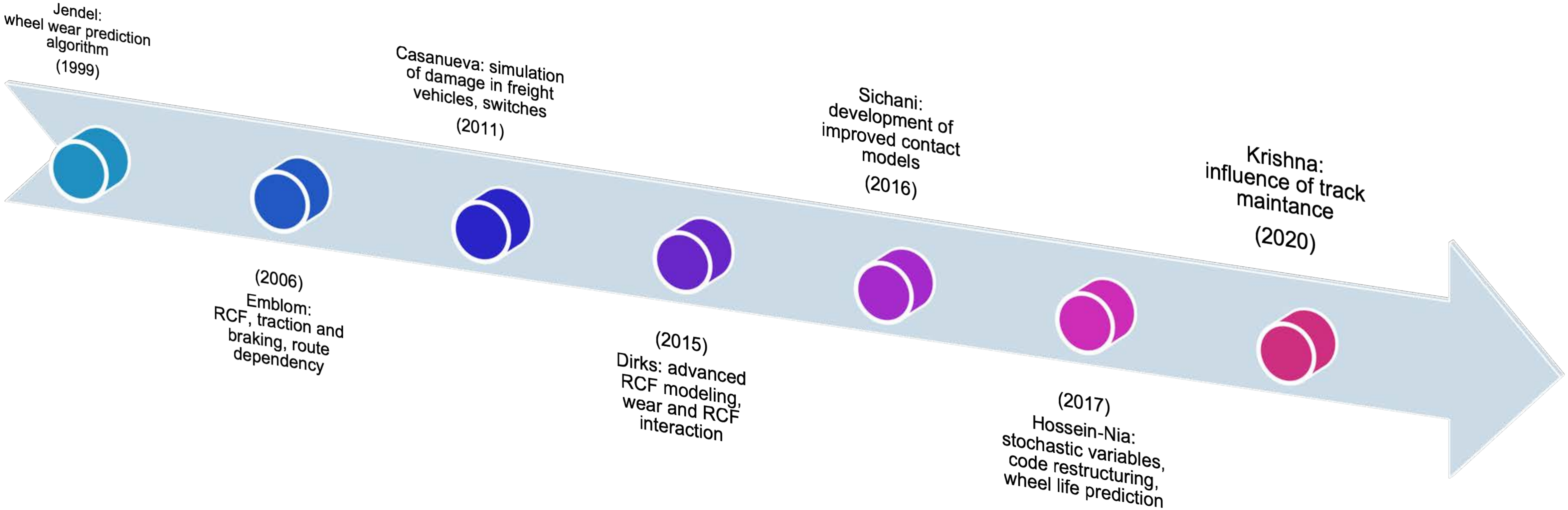
Background

- About 40% of track maintenance / renewal costs in Sweden are attributed to rail wear and RCF [1]: **Rail Surface Damage**
- The maintenance activities associated with damage due to **wear and RCF are interlinked**
- The maintenance activities **influence the wheel-rail dynamic interactions** which in turn **influences the damage process**.



[1] A. Smith, et al., “Estimating the relative cost of track damage mechanisms: combining economic and engineering approaches,” Proc. Inst. Mech. Eng. Part F J. Rail Rapid Transit, vol. 231, no. 5, pp. 620–636, 2017.

Wheel-Rail contact damage models



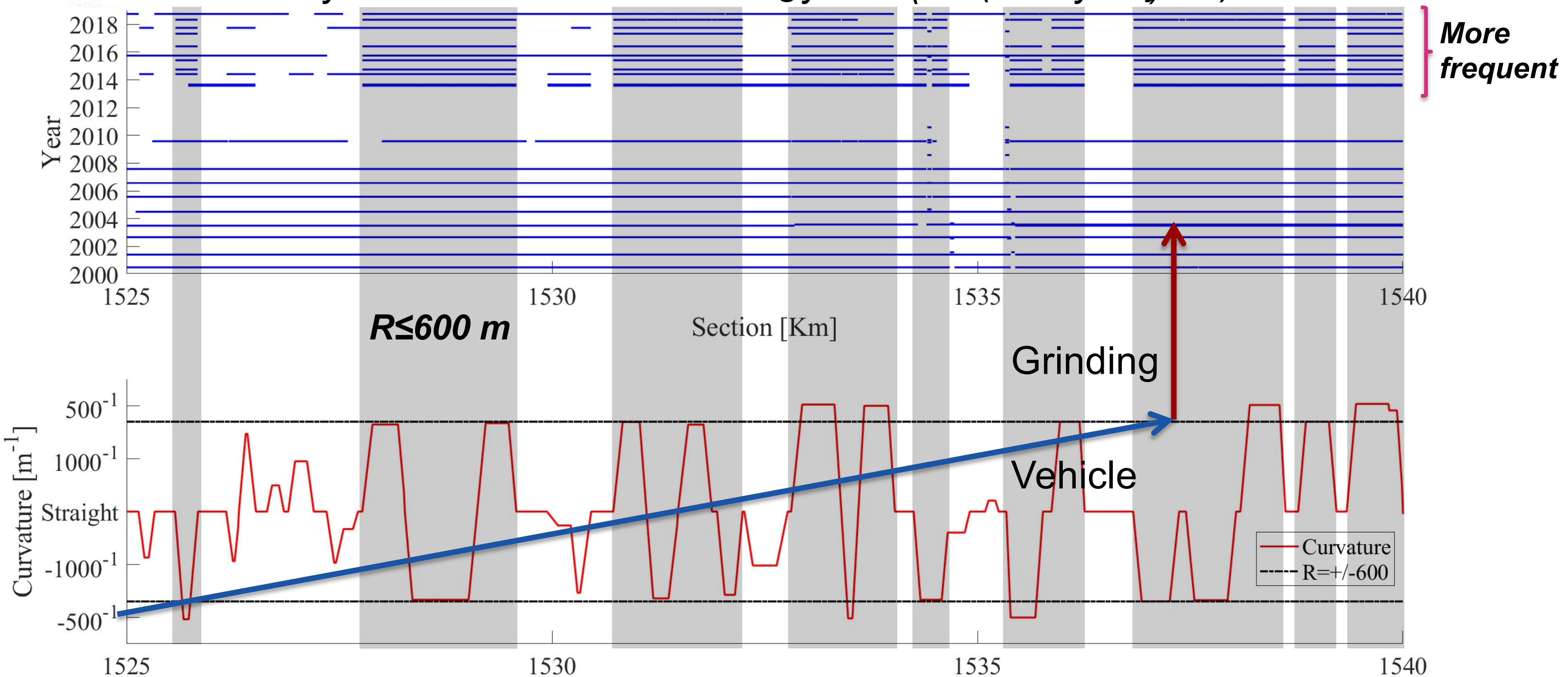
Evolution of the KTH Damage Model

Calculation of rail damage – Optimisation of grinding intervals

Significance of maintenance interventions

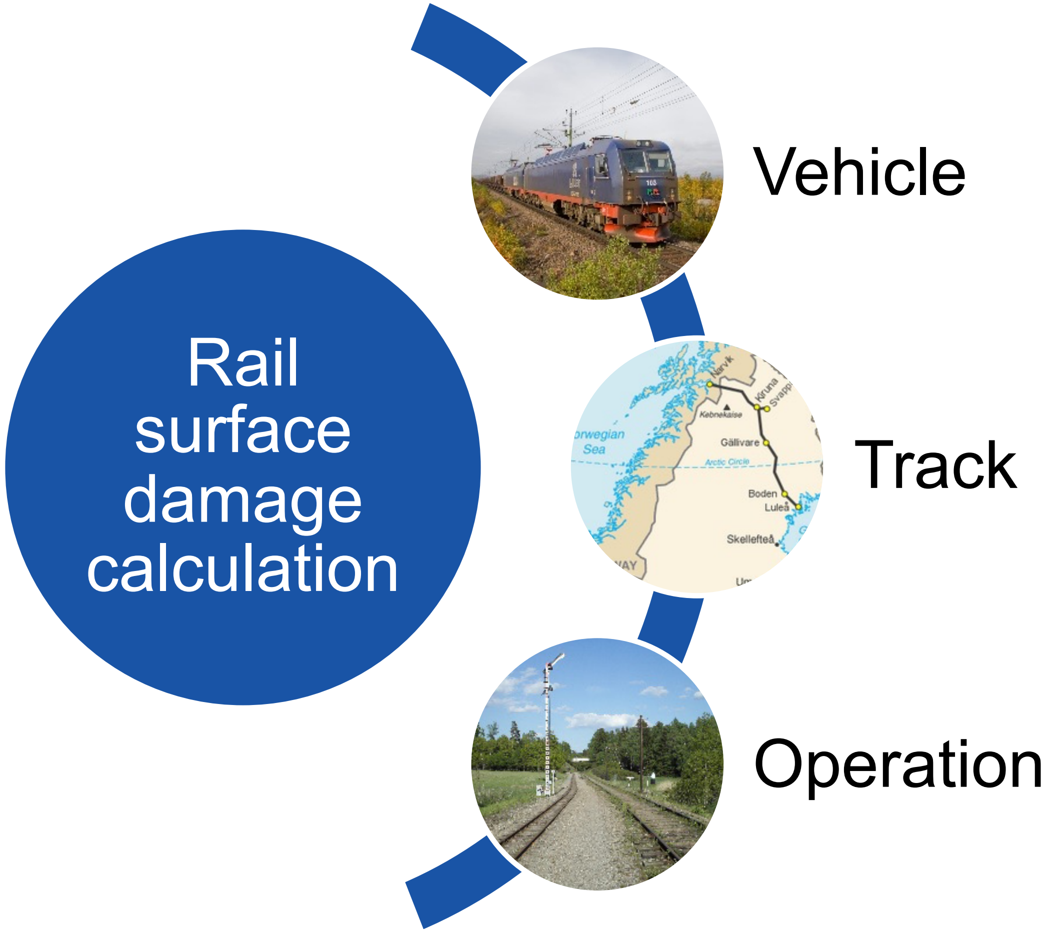
Germany: Rail cross section over 9 years (17 MGT/year)*

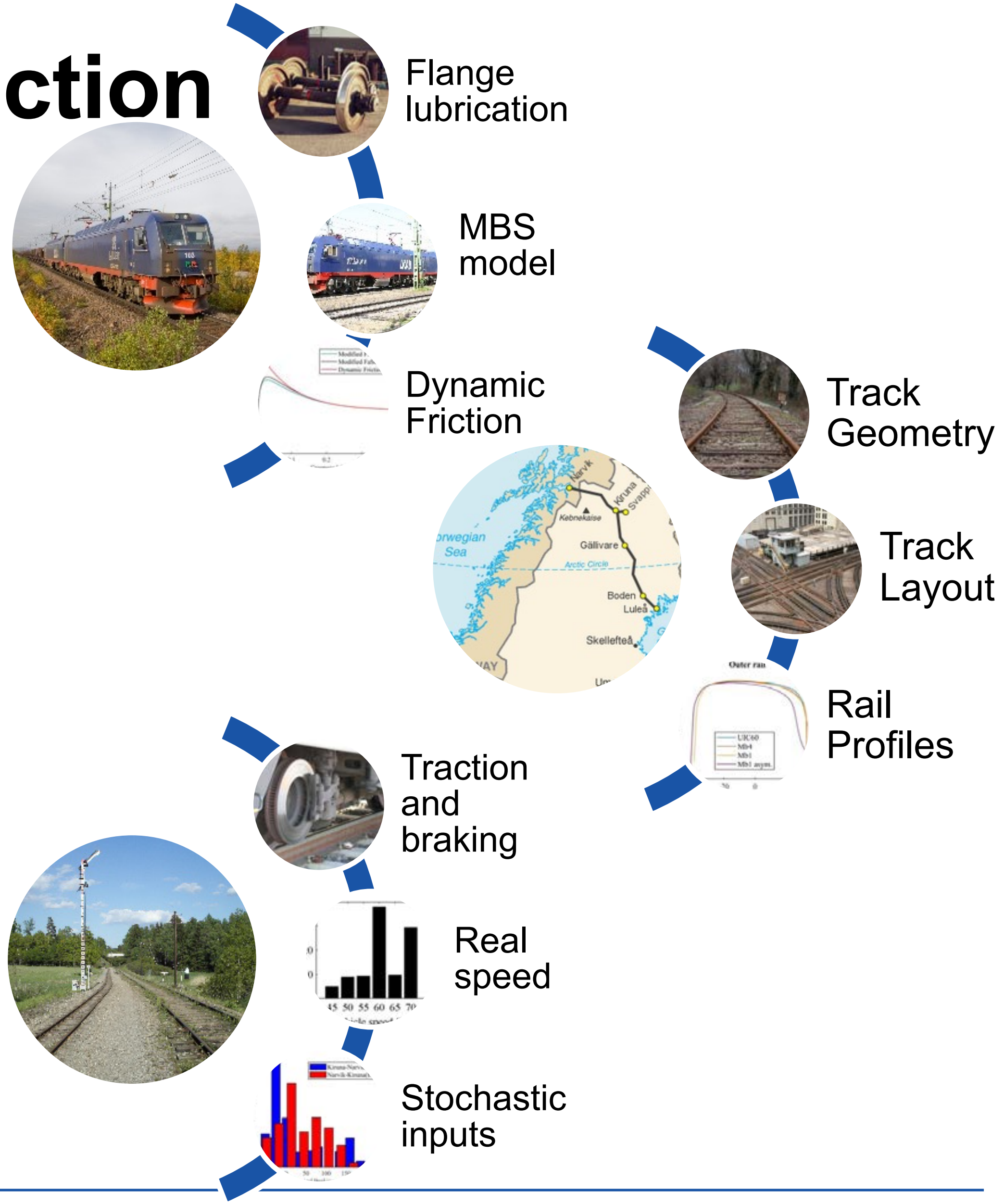
Swedish Iron-ore line: Grinding schedule (34 MGT/year)



*[1] Schoech et al. (2006)

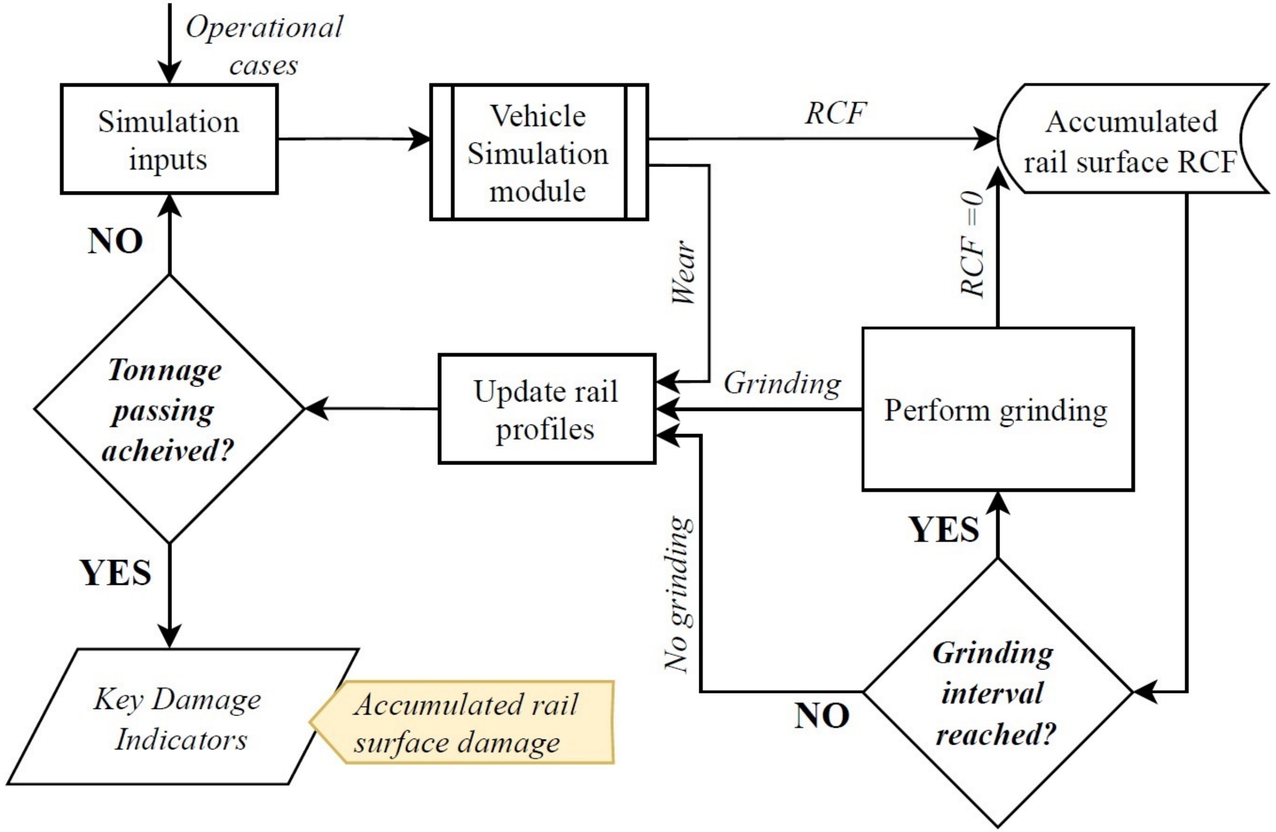
Simulation based
Rail surface damage prediction





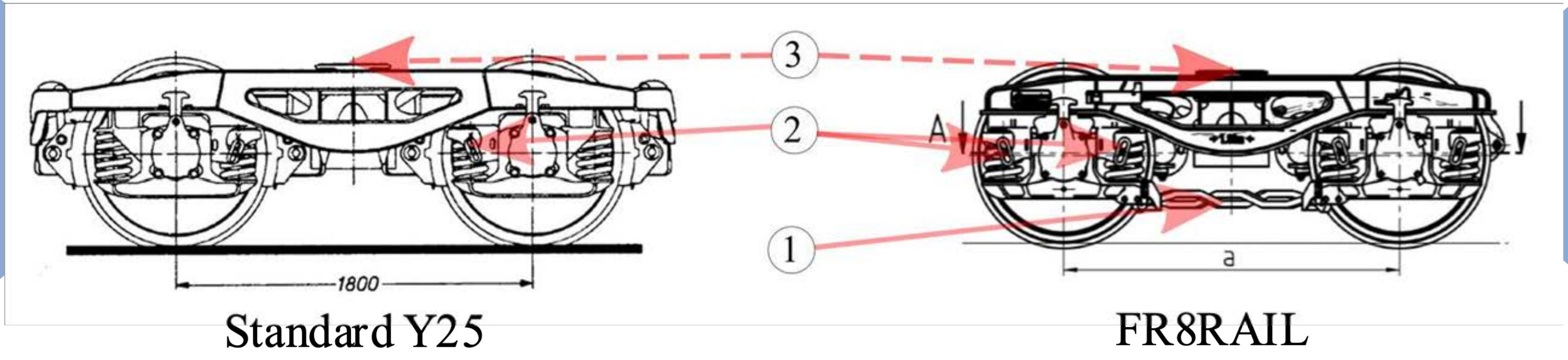
Calculating long term rail surface damage

- A MBS simulations-based method to assess long term accumulated rail surface damage due to
  - Vehicle passing
  - Intermediate maintenance actions



Comparing bogie designs

1. Cross bracing linkages
2. Double Lenoir links
3. Sidebearer longitudinal clearance



Elements of simulation modelling

Vehicle Designs
- Suspension elements
- Axle loads
- Wheel profiles

Track operation
- Track design geometries
- Friction levels
- Operating speeds
- Rail profiles

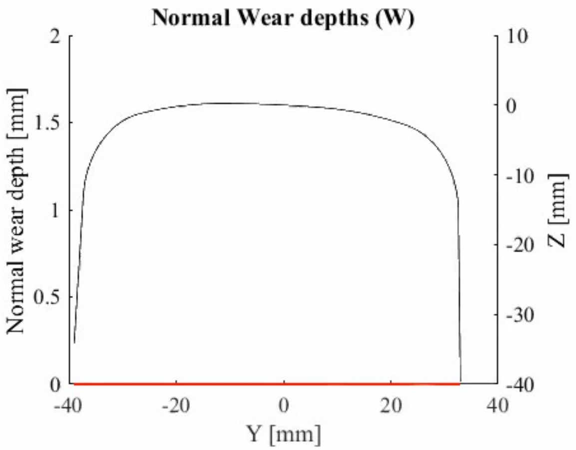
Maintenance
- Type (Grinding/milling)
- Intervals
- Depths

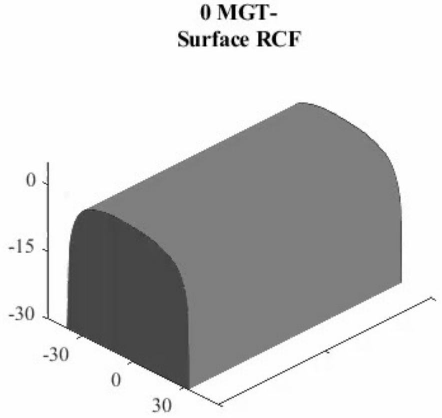
Rail surface damage evolution

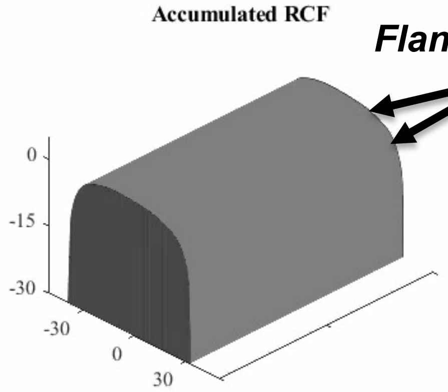
Standard Y25 bogie

R = 450 m
Outer rail
100 MGT
~4 years

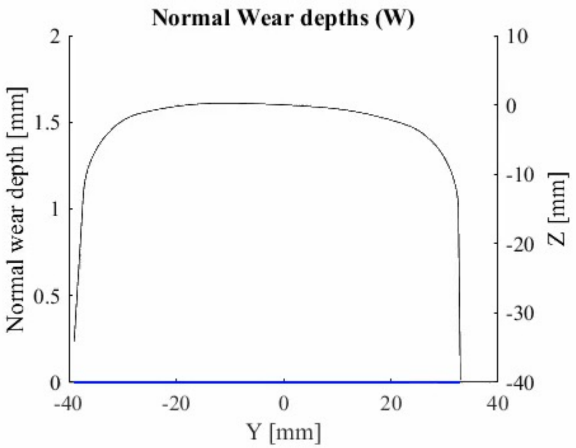
FR8RAIL bogie

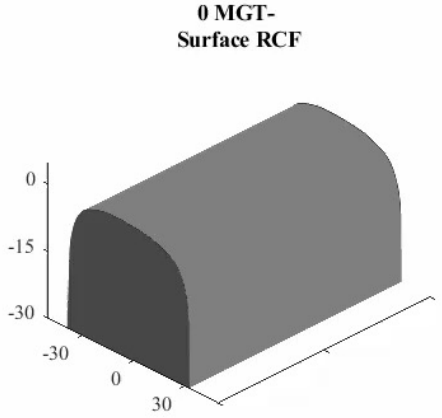


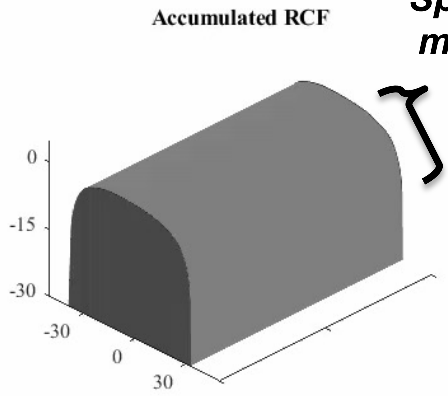




Flange & head







Spread but mostly on head

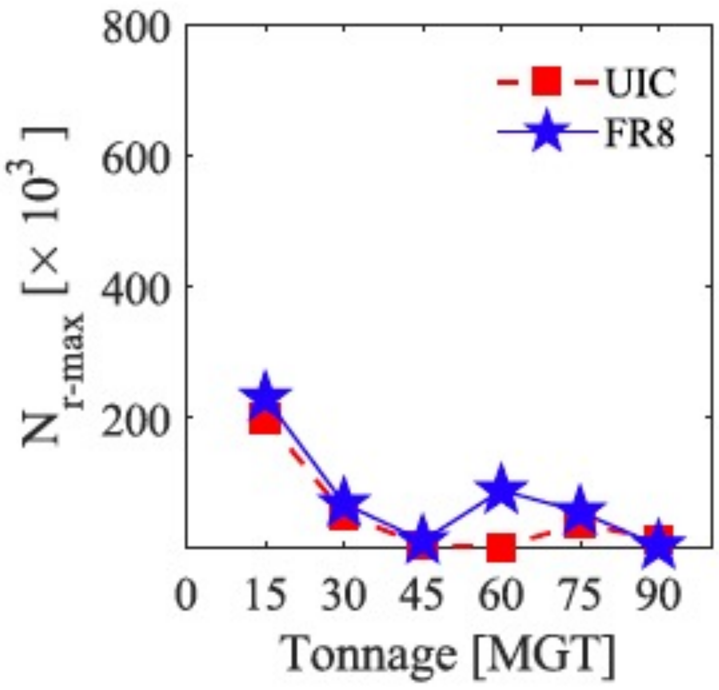
Wear depth

Surface RCF

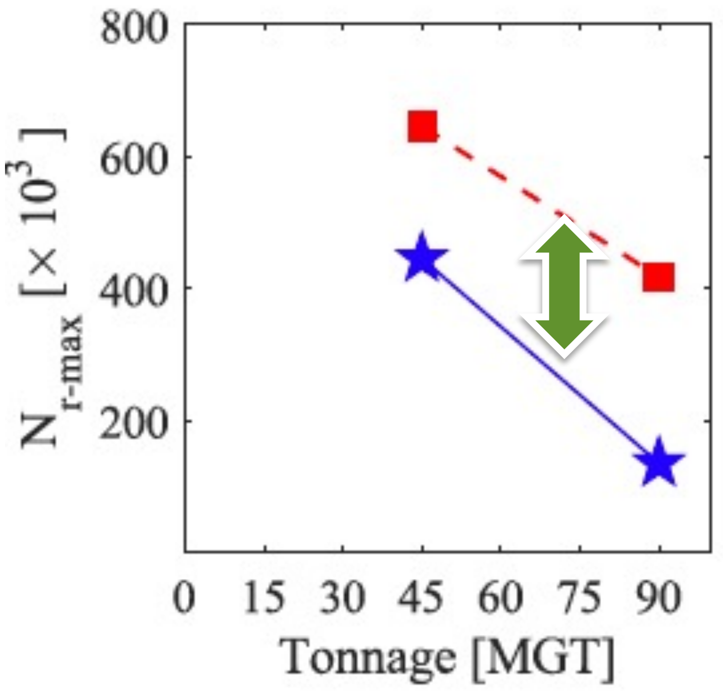
Accumulated RCF

Optimization of grinding intervals

RCF accumulation on the rail surface just before each grinding pass



R450



R1500

Opportunity to modify grinding intervals w.r.t running gear behaviour for different curve radii.

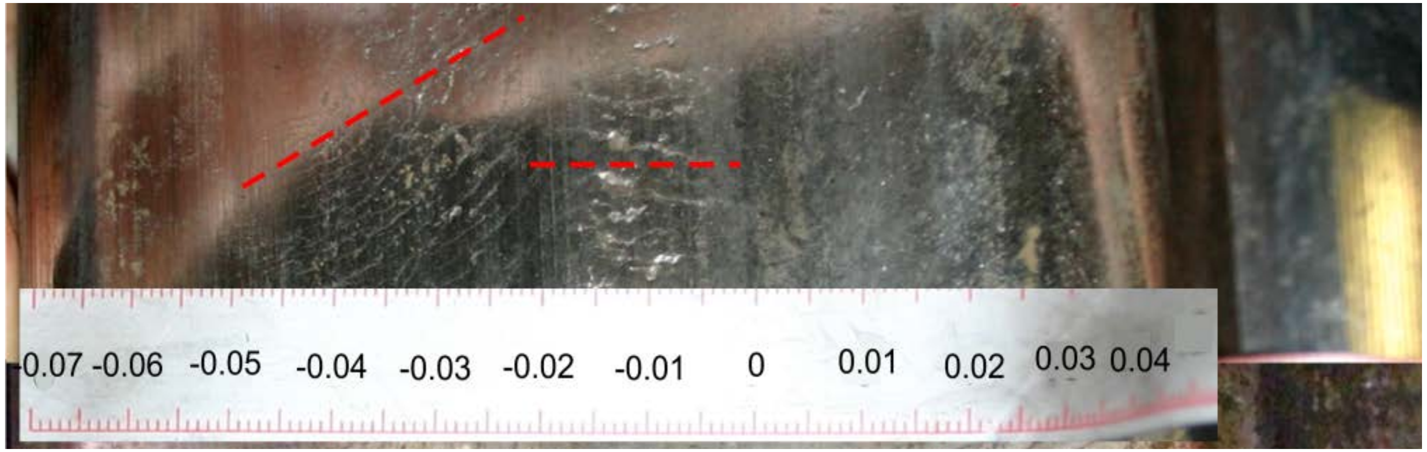
It is possible also to optimize w.r.t.:

- **Weather conditions**
- **Operational changes**
- **Wheel profile changes**
- **…**

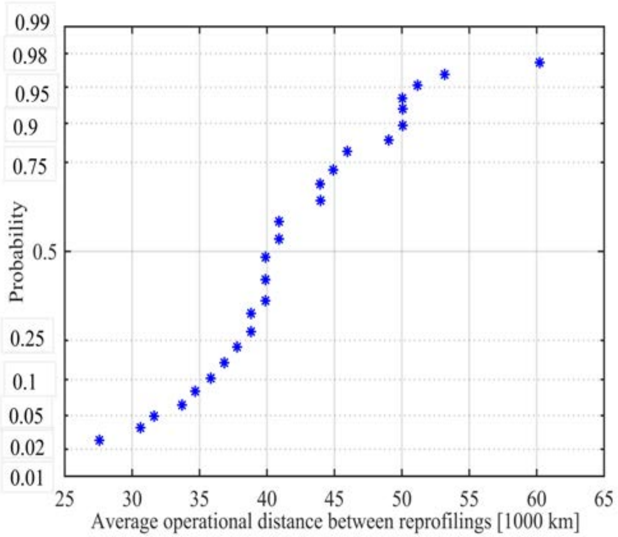
V. V. Krishna, S. Hossein-Nia, C. Casanueva, S. Stichel, Long term rail surface damage considering maintenance interventions, Wear, vol. 460, 2020

Calculation of wheel damage – Wheel life prediction

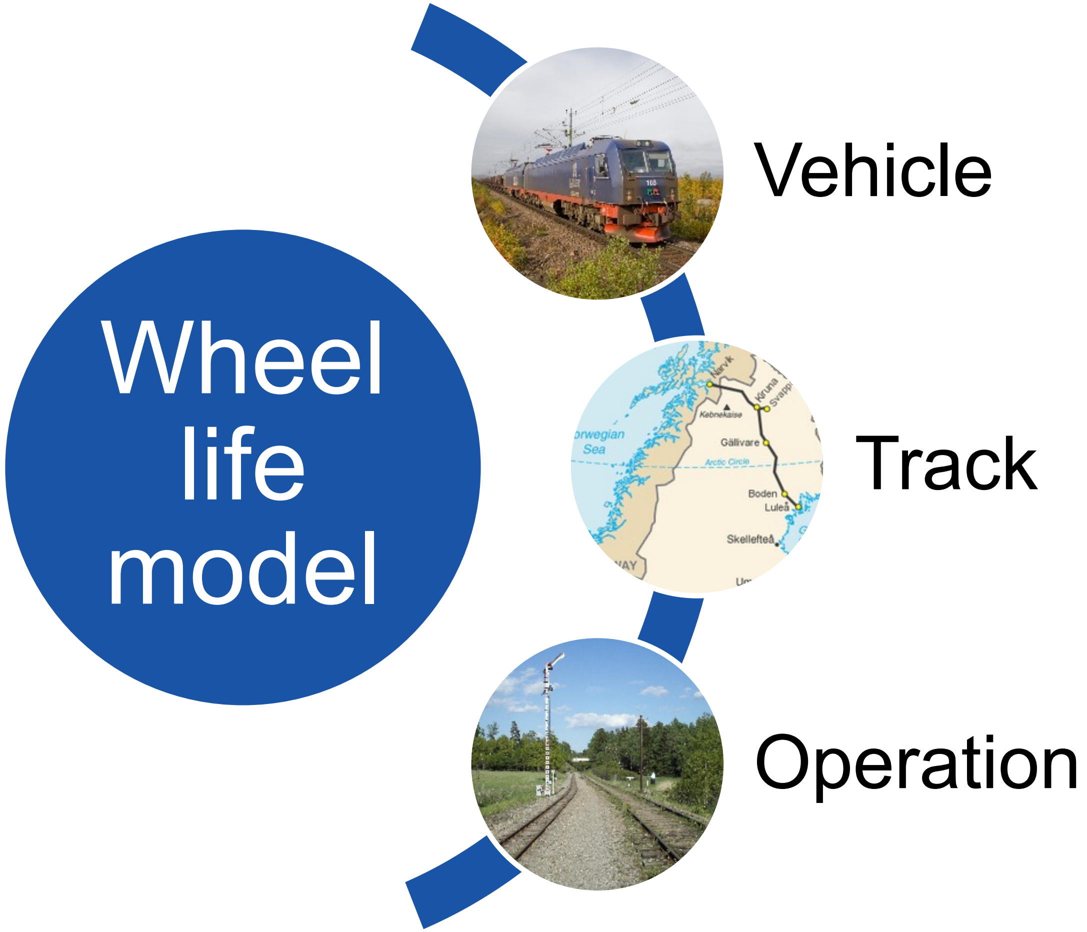
Wheel life prediction

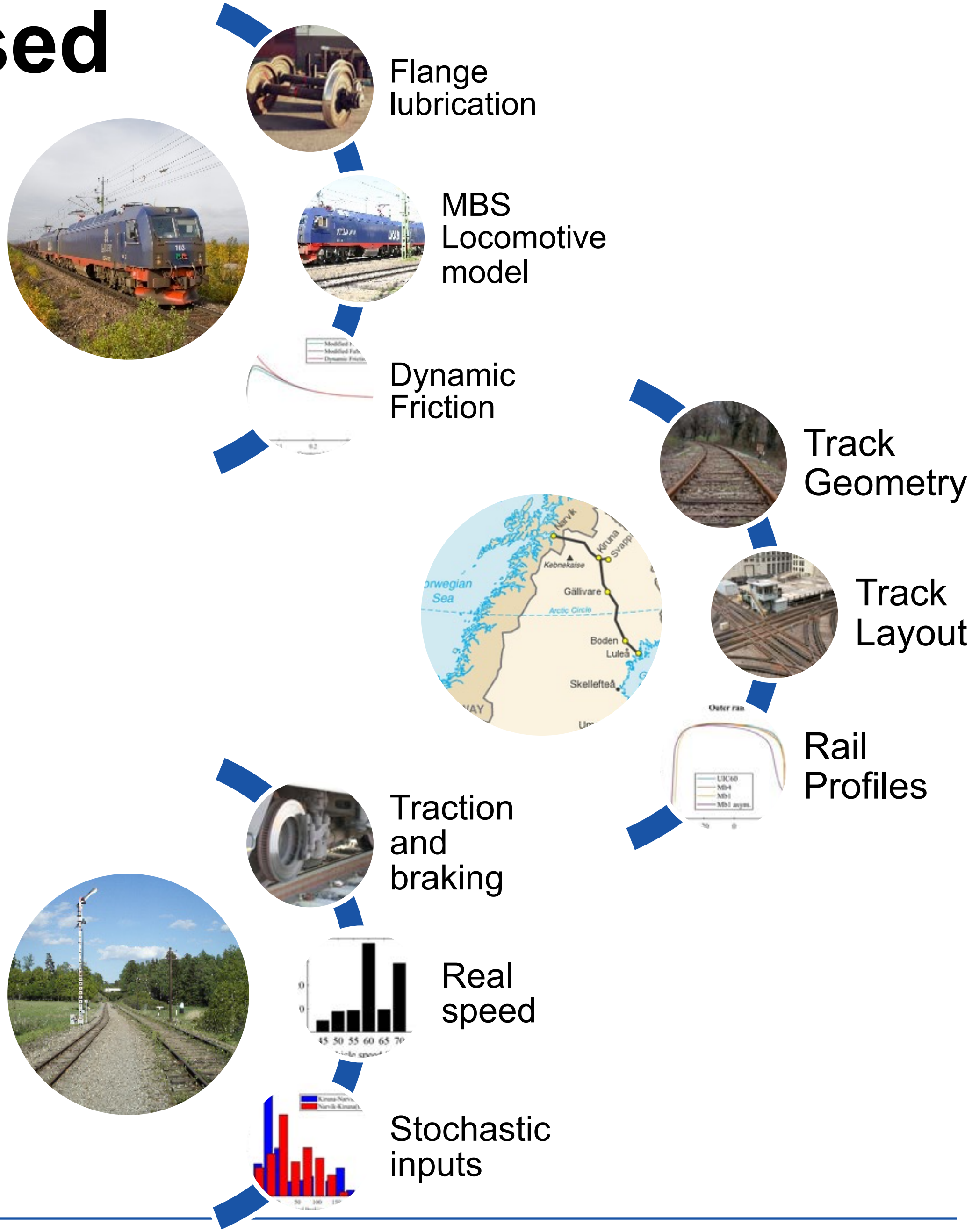


Anders Ekberg, Chalmers

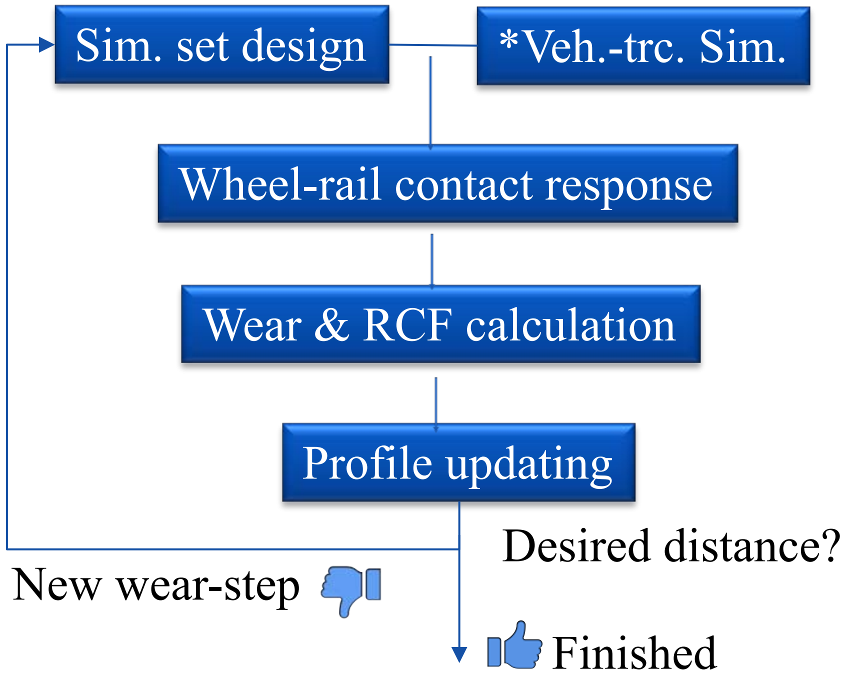


Rail Vehicle Dynamics based Wheel Life prediction



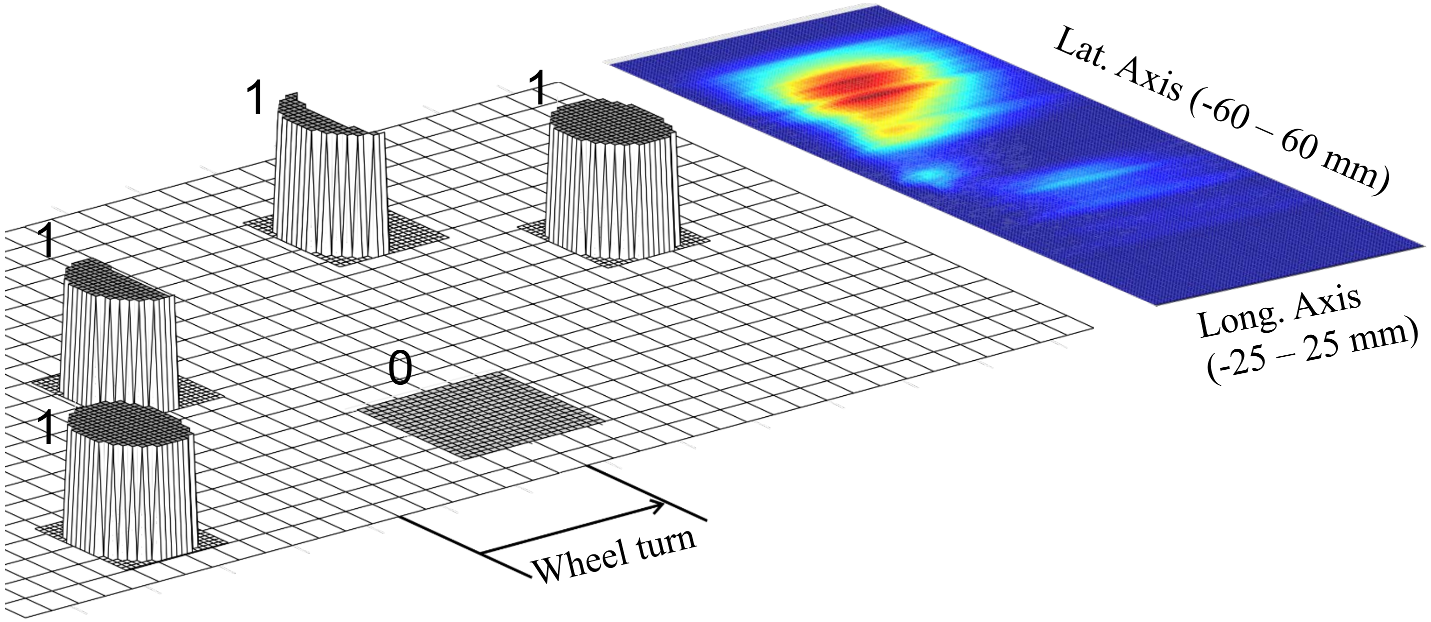


RCF Calculation



RCF calculation

1. Check the exceedance of the yield limit in shear in each element of the contact mesh
2. Count the amount of incidents where #1 occurs



RCF calculation

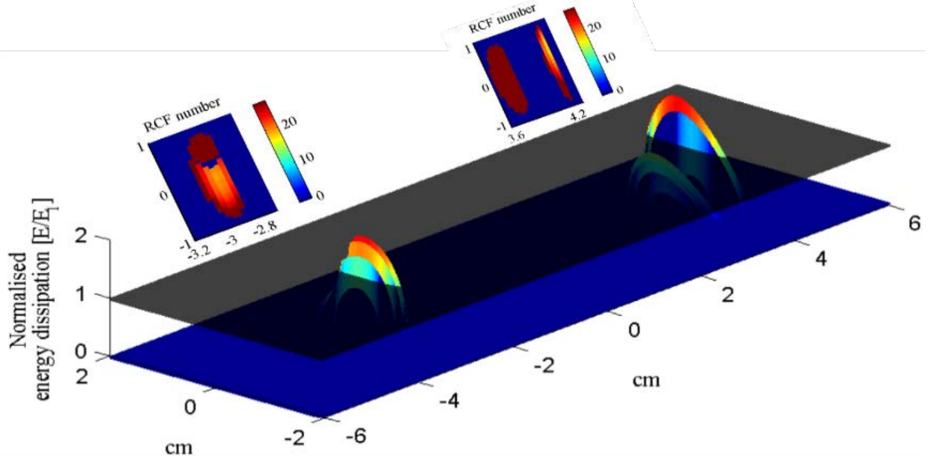
1. Check the exceedance of the yield limit in shear in each element of the contact mesh
2. Count the amount of incidents where #1 occurs
3. Correct the RCF-number (Nr) values by energy dissipation method (Burstow)

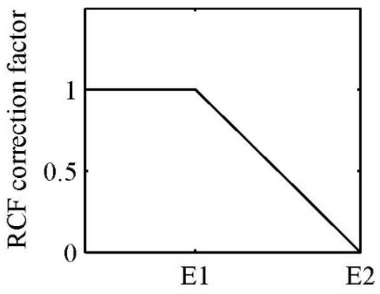
$$\bar{E}_i = \frac{\nu_i \cdot A}{2\sqrt{3}}(\sigma_y + \sigma_U), \text{for } i = 1, 2$$

ν_i are 0.3% and 1%

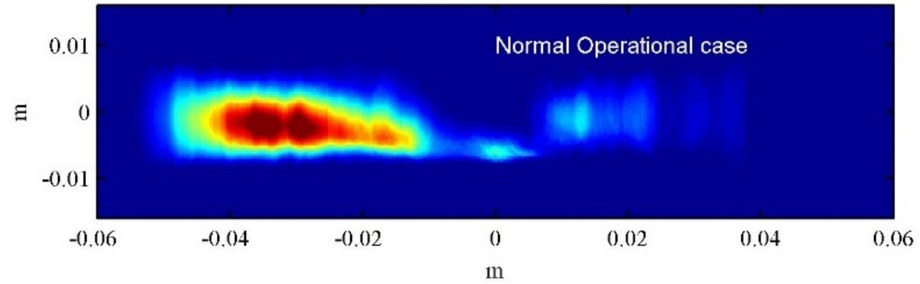
σ_y and σ_U are material yield limit and its ultimate tensile strength

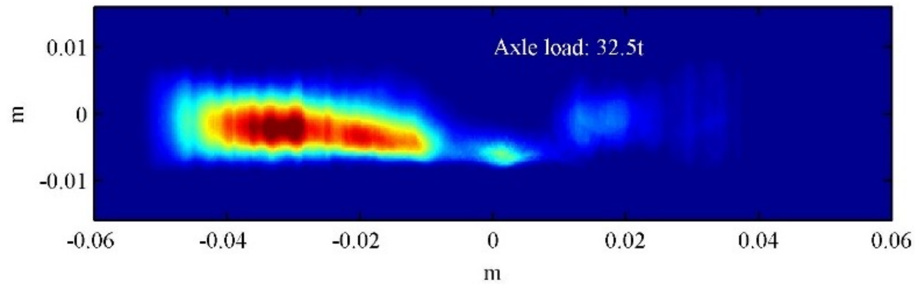
$$E(x,y) = \tau_{zx}(x,y) \cdot (\nu_x - \phi \cdot y) + \tau_{zy}(x,y) \cdot (\nu_y + \phi \cdot x)$$

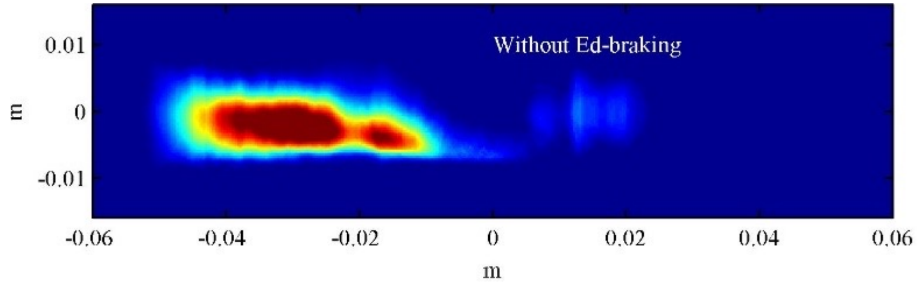


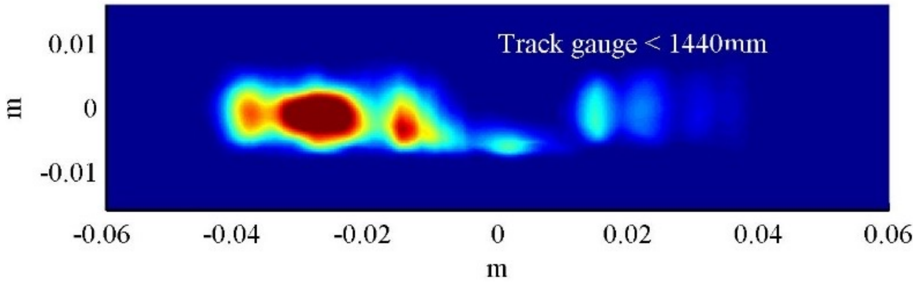


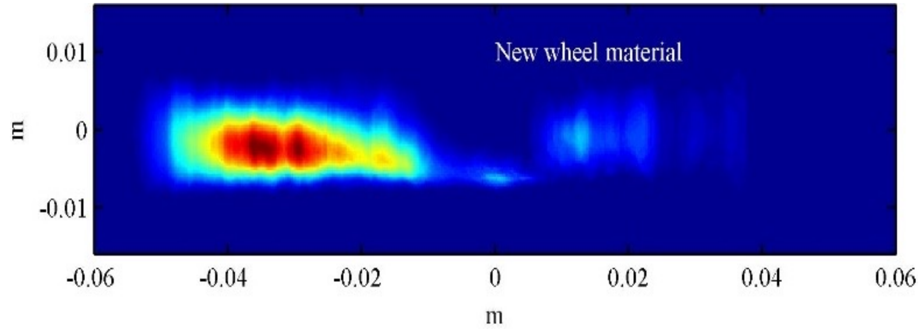
RCF results (N_r)





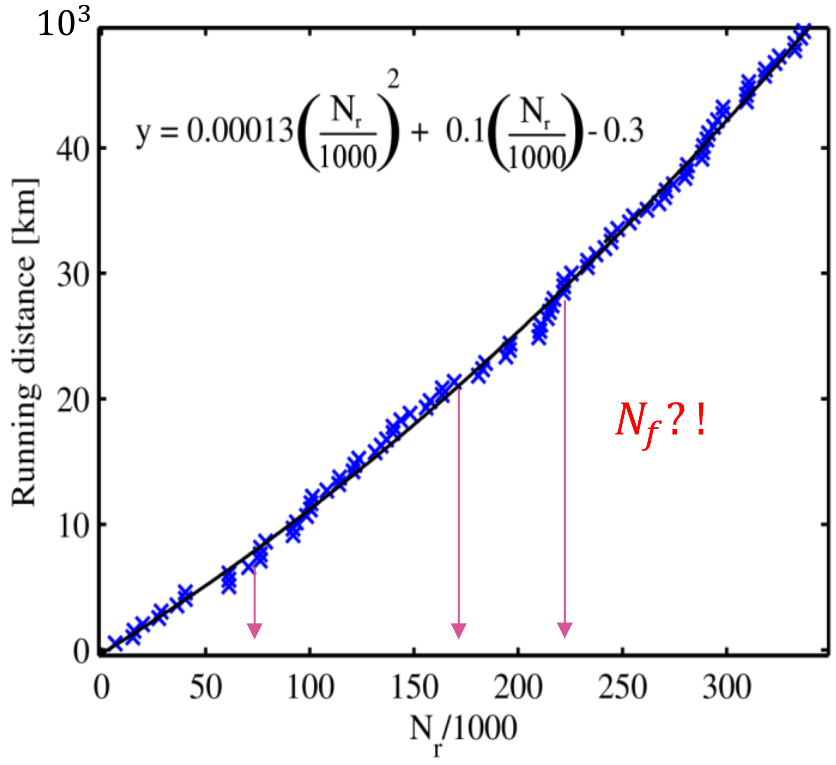






Simulated RCF results for various operational cases after 50 000km; maximum value for the colour-bar is set to 300 000 RCF number.

Wheel life prediction model

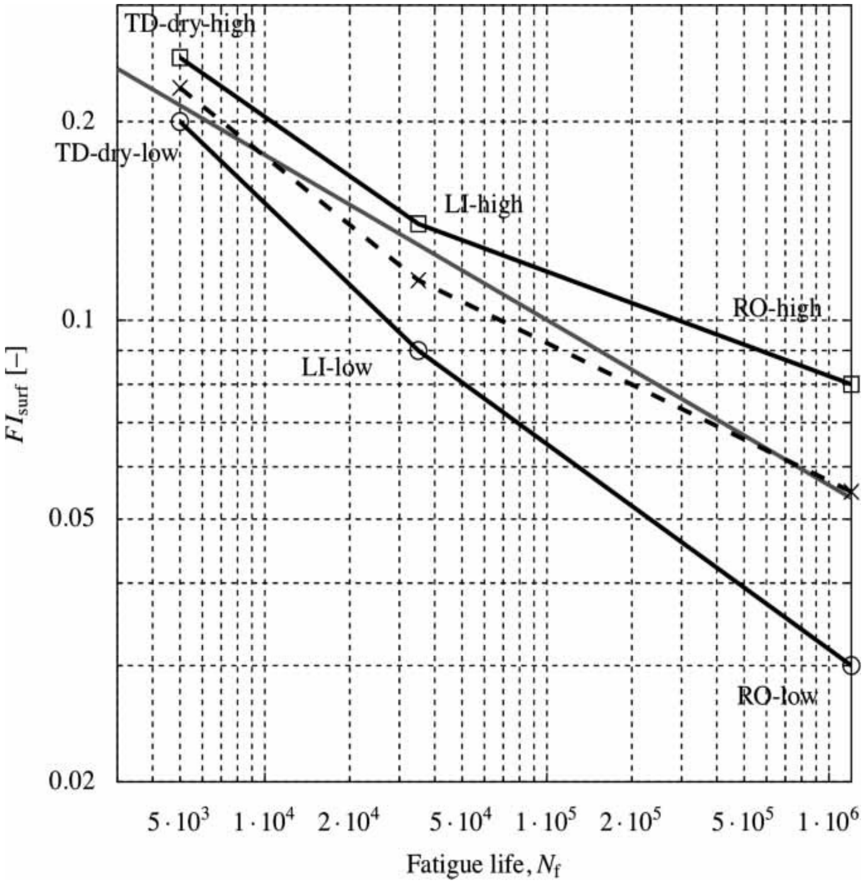


N_f Fatigue life

Wheel life prediction model

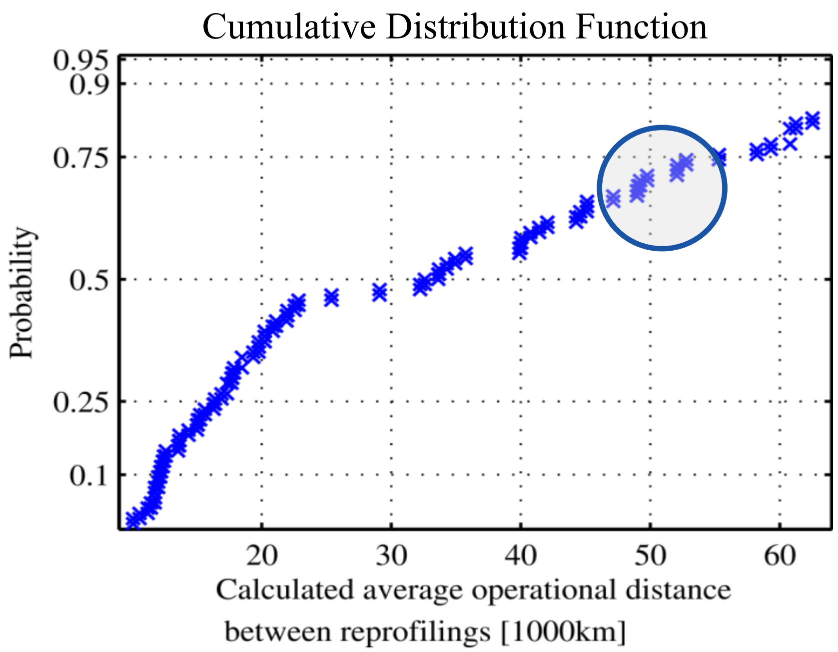
$$N_f = \frac{10}{FI_{surf}^4}$$

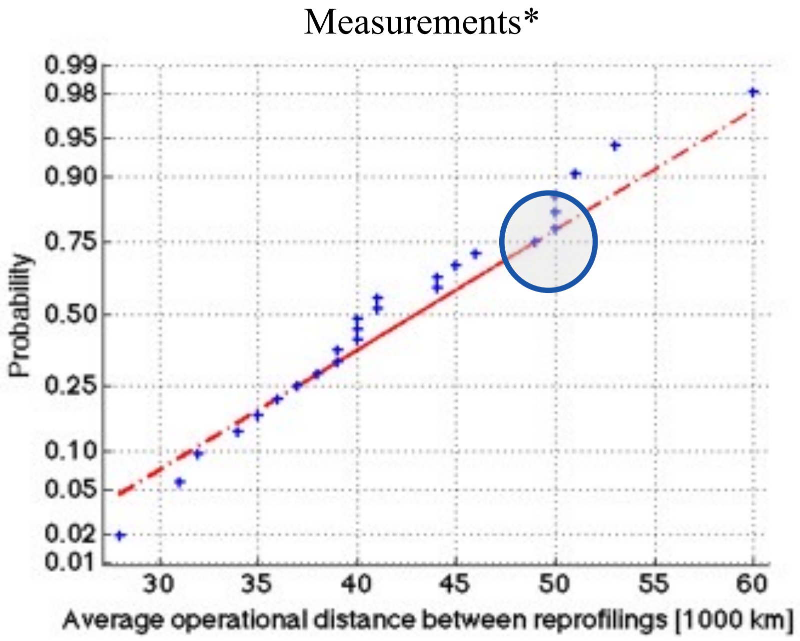
*Fatigue life: N_f



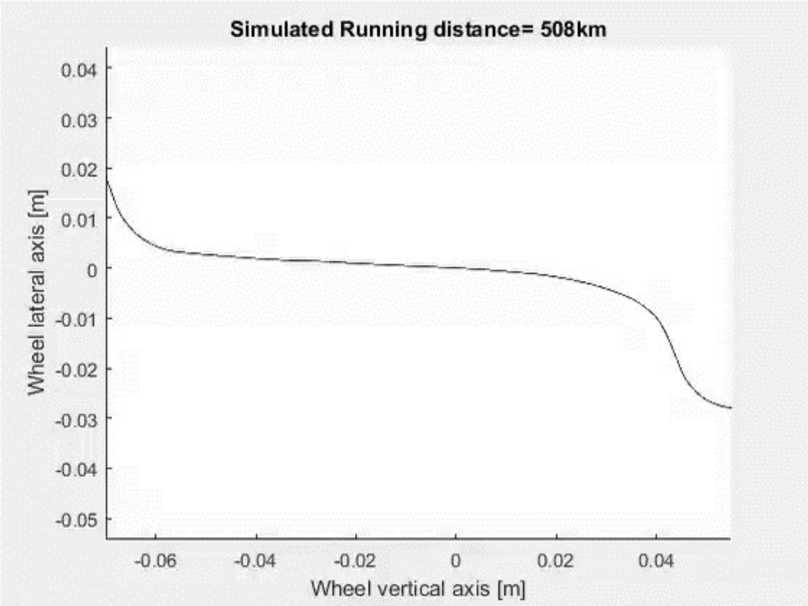
*Kabo E., Ekberg A., Torstensson PT. and Vernersson T. Rolling contact fatigue prediction for rails and comparisons with test rig results. Proceedings of the Institution of Mechanical Engineers Part F-Journal of Rail and Rapid Transit. 2010; 224: 303-317.

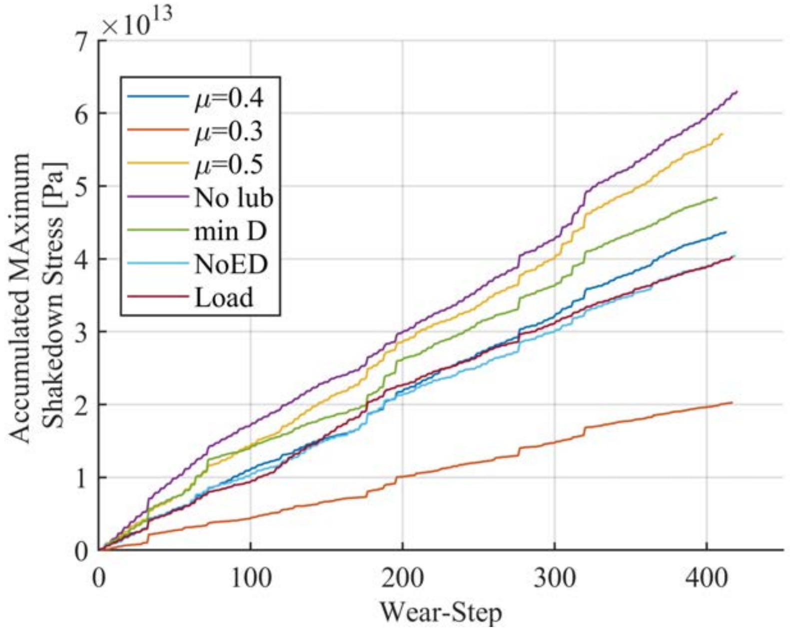
Wheel life prediction model: results

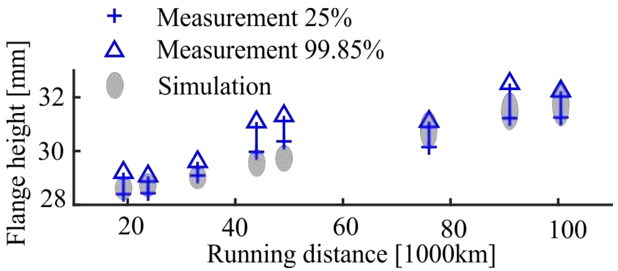


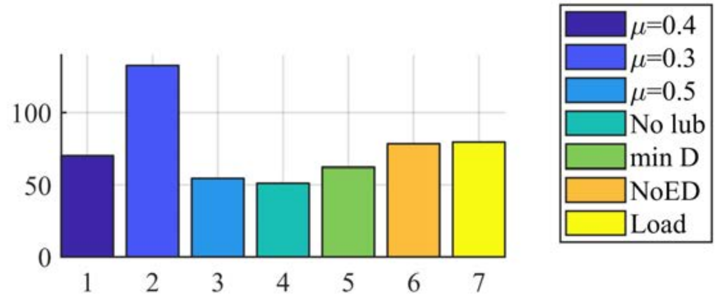


Wheel Life prediction: wear and RCF





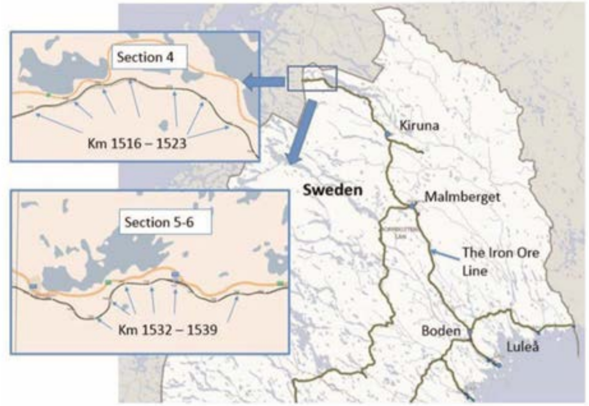


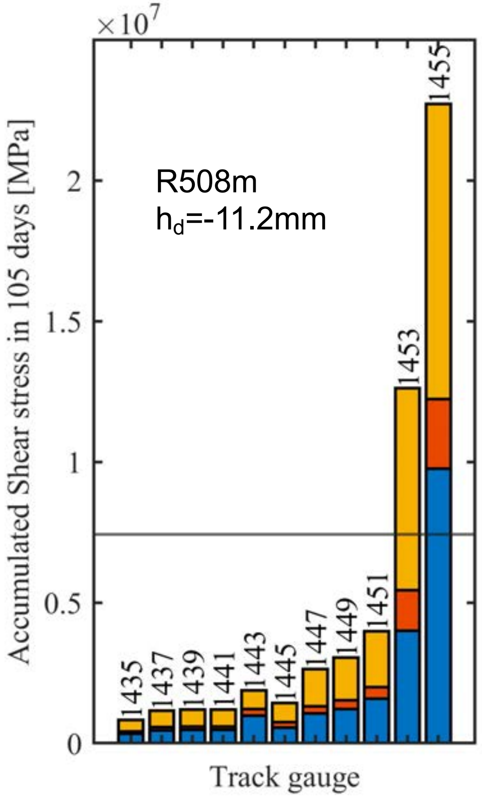


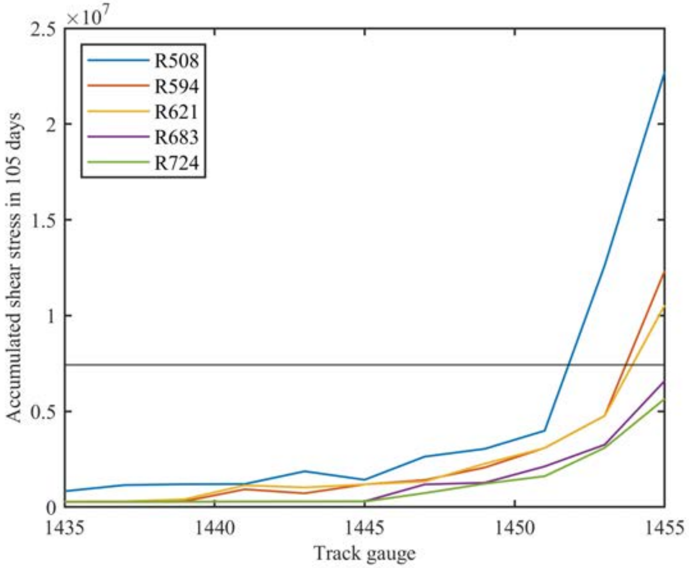
S Hossein-Nia, S Stichel, 2019, *Multibody simulation as virtual twin to predict the wheel life for Iron-ore locomotive wheels* International Heavy Haul Association Conference, IHHA 2019, Narvik

Calculation of rail damage – Influence of track gauge

Rail Life prediction





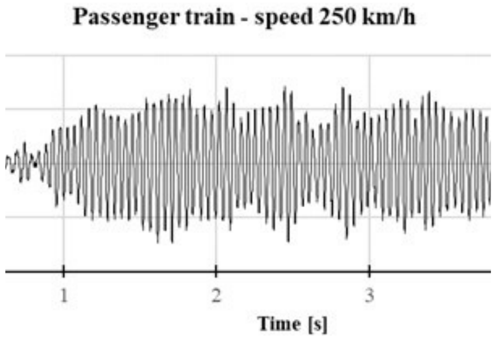


J. Flodin, 2020, *Investigate the track gauge widening on the Iron-ore line and suggest maintenance limits*, KTH Master thesis

Machine Learning Algorithms
for condition monitoring and fault diagnostics

Track geometry

Local track defects



Running instability

Component failure

Rail Vehicle Dynamics Informed Machine Learning Algorithms for **onboard** condition monitoring and fault diagnostics

Summary

The presented tools

- Show good agreement with field observations

and could be used to

- Optimise rail grinding or wheel turning intervals with respect to
  - Track section
  - Operational changes
  - Vehicle type
  - Changes of wheel or rail profile type
  - …
- Detect faults in vehicle and/or track with help of **Rail Vehicle Dynamics** Informed Machine Learning Algorithms