Load-dependent influences on rail damage mechanisms

Methodology for wear assessment based on empirical data

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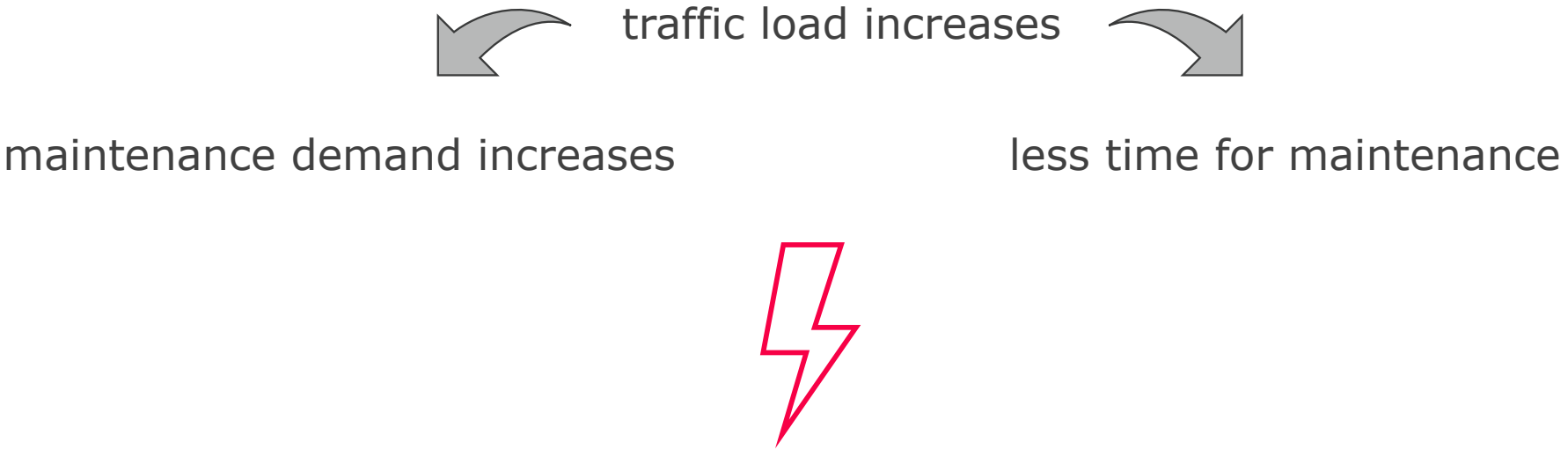
ICRI Webinar

Graz | 09.12.2025

Storyline

- Introduction
- Background
- Methodology
- Results
- Further research

Introduction

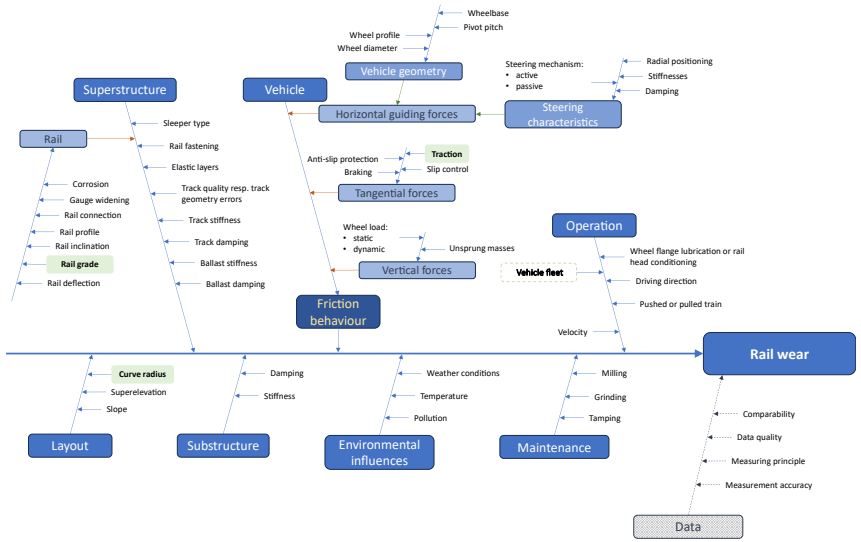


- Efficient maintenance planning & execution necessary!
- Forecasting as a tool for effective planning

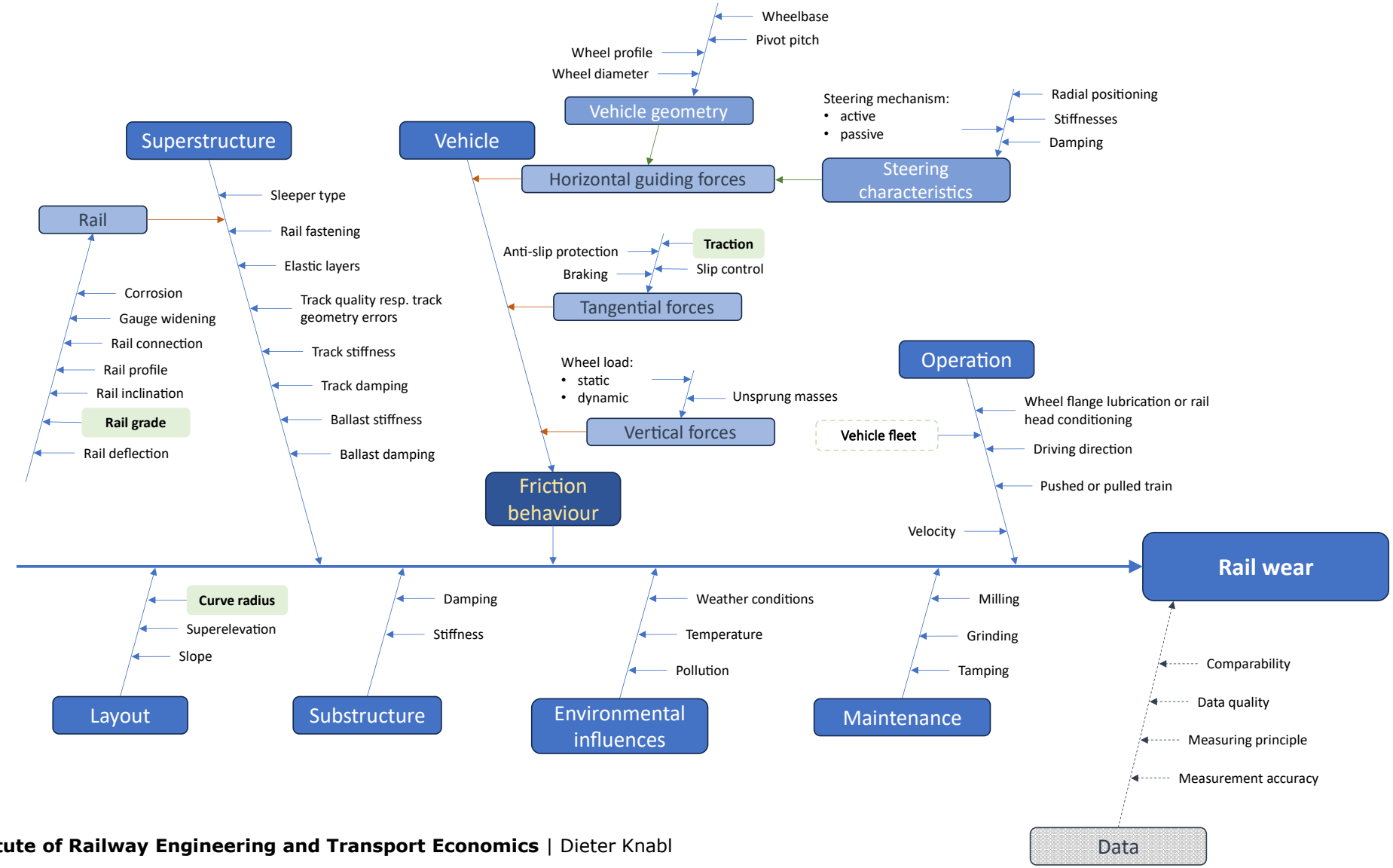
Background

- Predictive maintenance: established for track geometry maintenance – not for rails

- Need for deeper understanding of rail degradation mechanisms
- Influence of boundary conditions



Possible factors influencing rail wear



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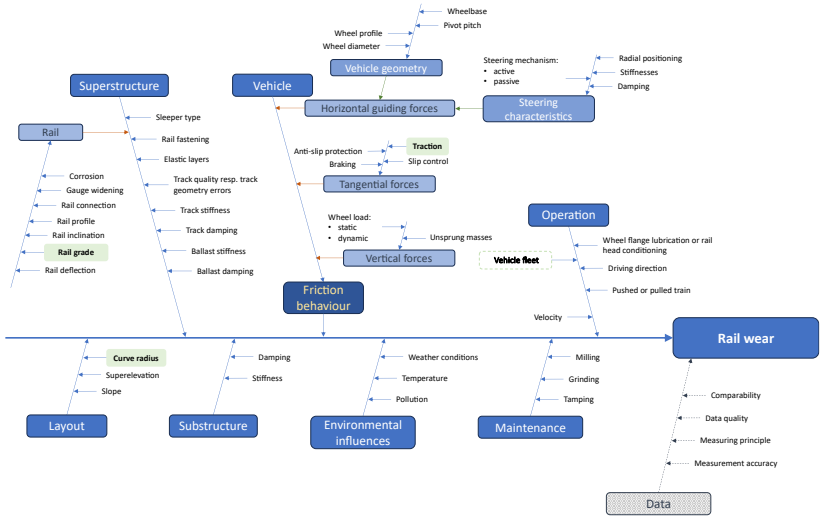
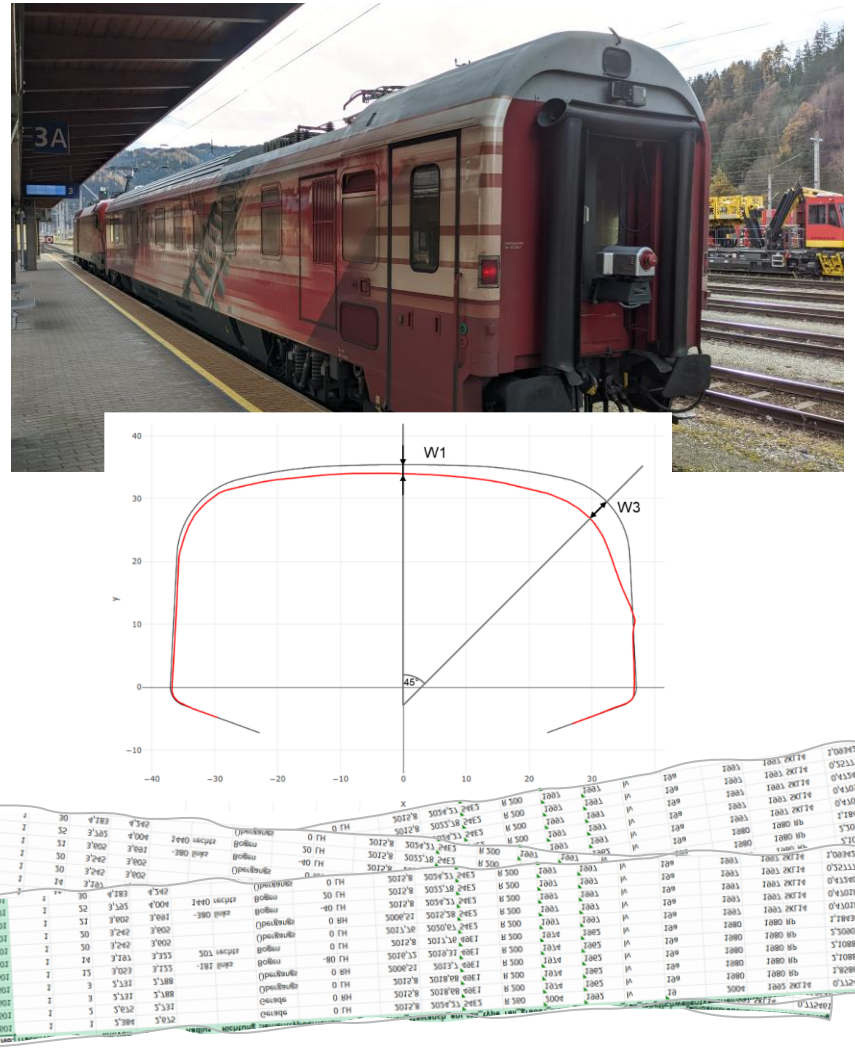


- Identification of key influencing factors
- Derive prediction models as function of boundary conditions

- Methodology for automated rail wear assessment as cornerstone for development towards data-driven rail maintenance planning

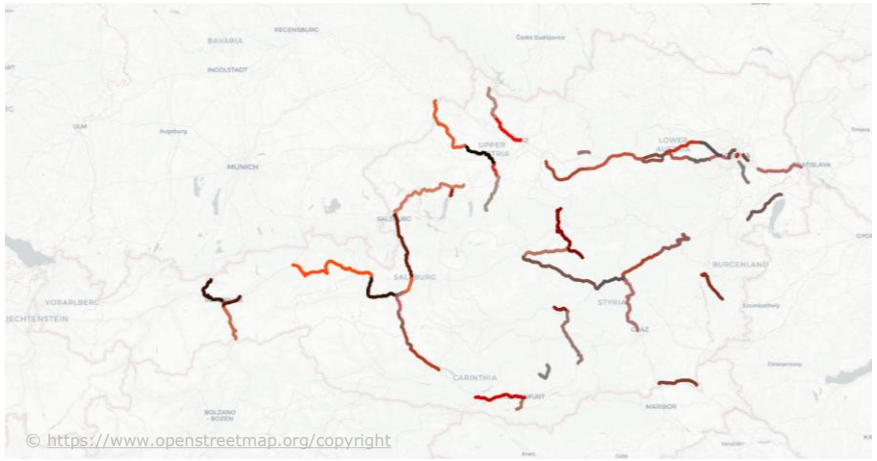
Data basis

- Measurement data from ÖBB's track recording car
  - Lateral and vertical wear derived from measured rail profile
- Asset data for description of superstructure and layout
  - Type and installation date of each component
- Track loading expressed as gross tonnage
  - Long-term goal: find better suitable loading parameter
- Records of rail surface treatment
  - Documentation of milling and grinding actions



Selection of suitable routes and partitioning in elements

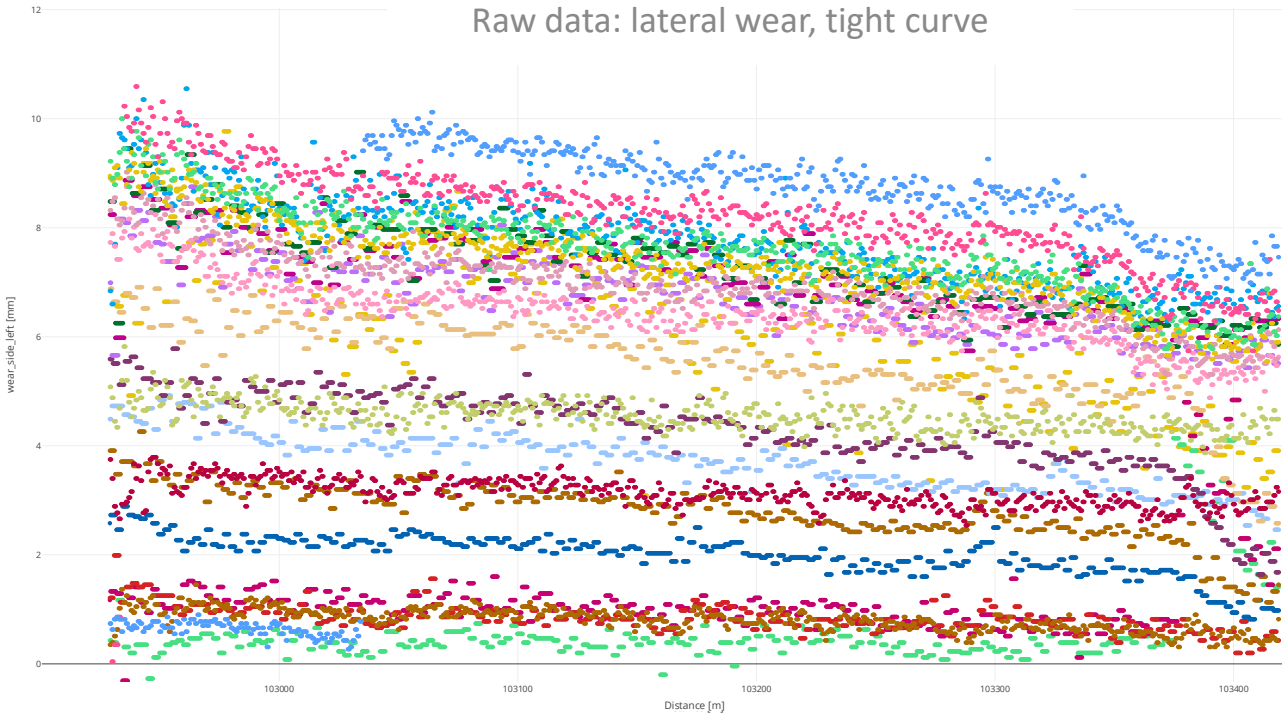
- Representative cross-section of network
  - Main lines & lower-traffic secondary lines
  - High-speed & conventional operation
  - Mountainous & flat routes
- General applicability is ensured



- Elements ≙ subsection with homogenous characteristics
  - Radius
  - Rail steel grade & profile
  - Sleeper type
- Enables linking wear behaviour to specific physical conditions

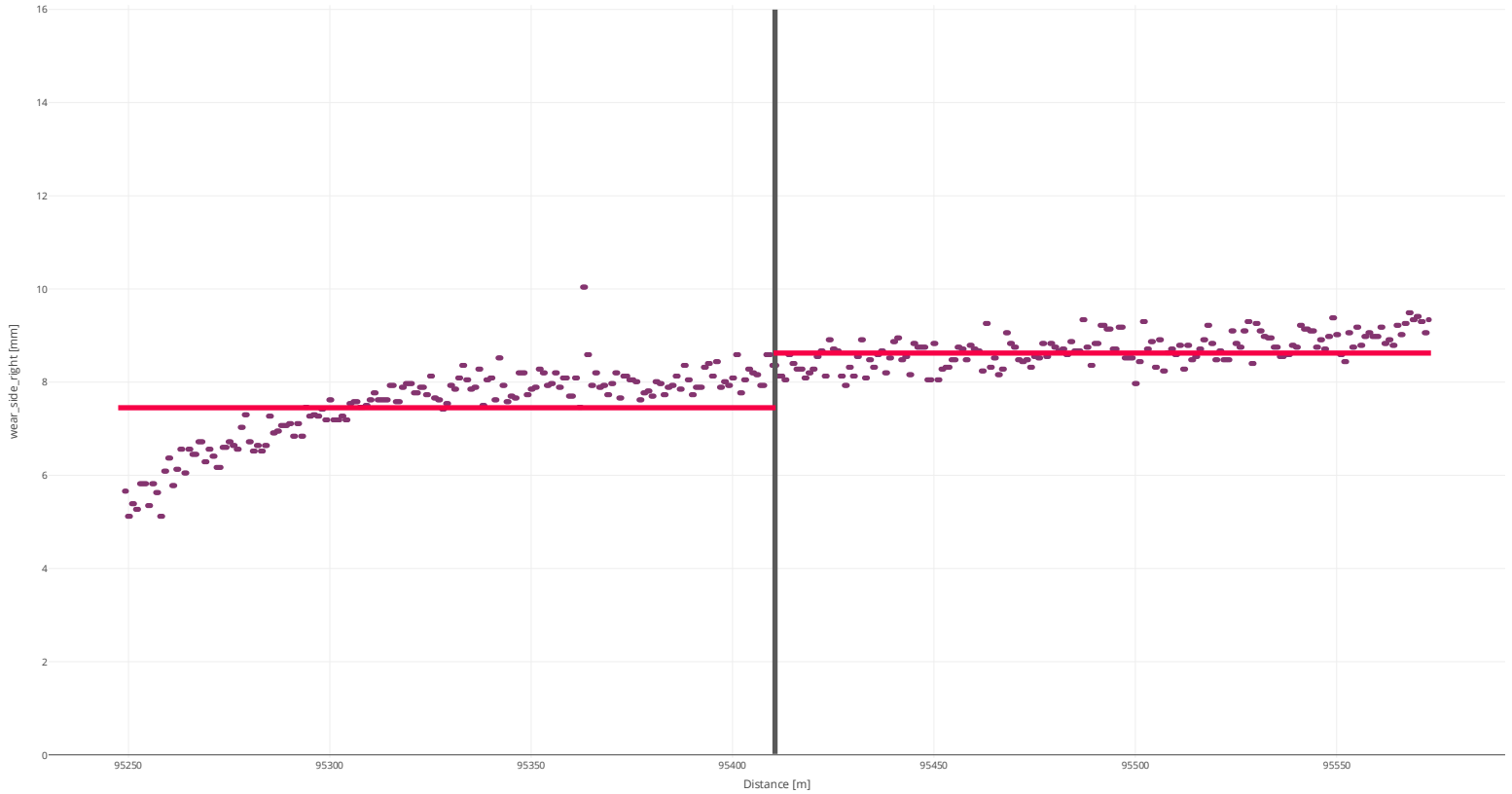
Evaluation methodology

- Averaging taking into account the curve-in effect
- Detection of unrecorded maintenance measures
- Evaluation of wear indicators for time series



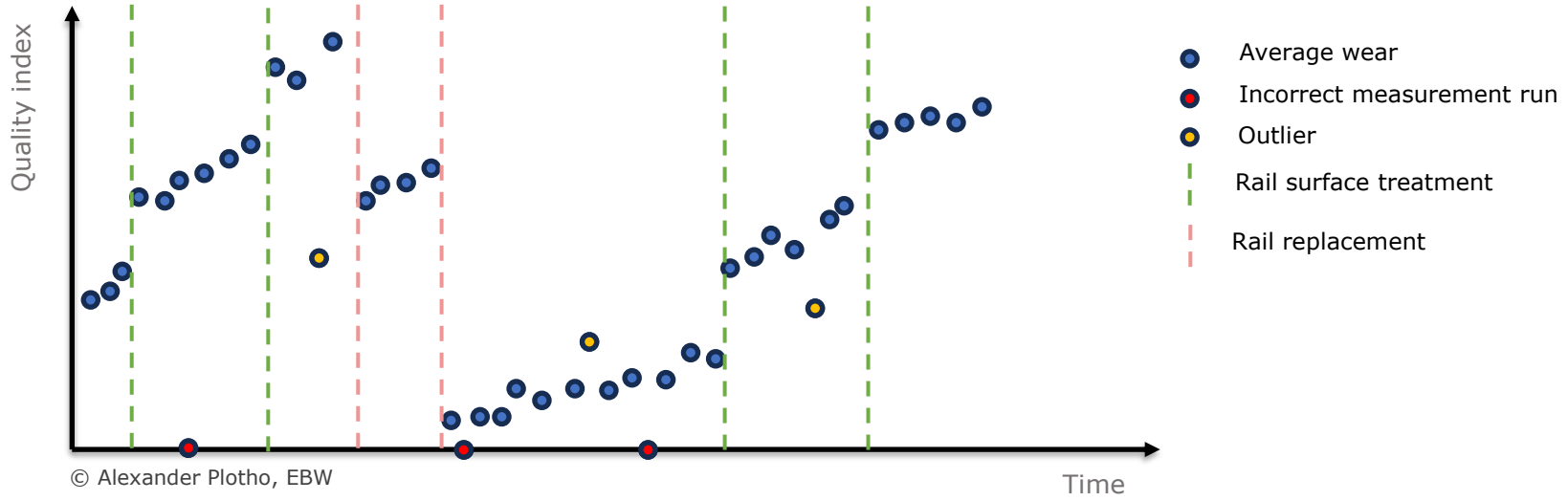
Dealing with the curve-in effect

- Method
  - Split each curve (incl. transitions) into two halves
  - Compute mean value for each half
  - Require ≥ 50 m valid data per half
  - Take higher mean as representative wear value
  - Exclude elements with insufficient data



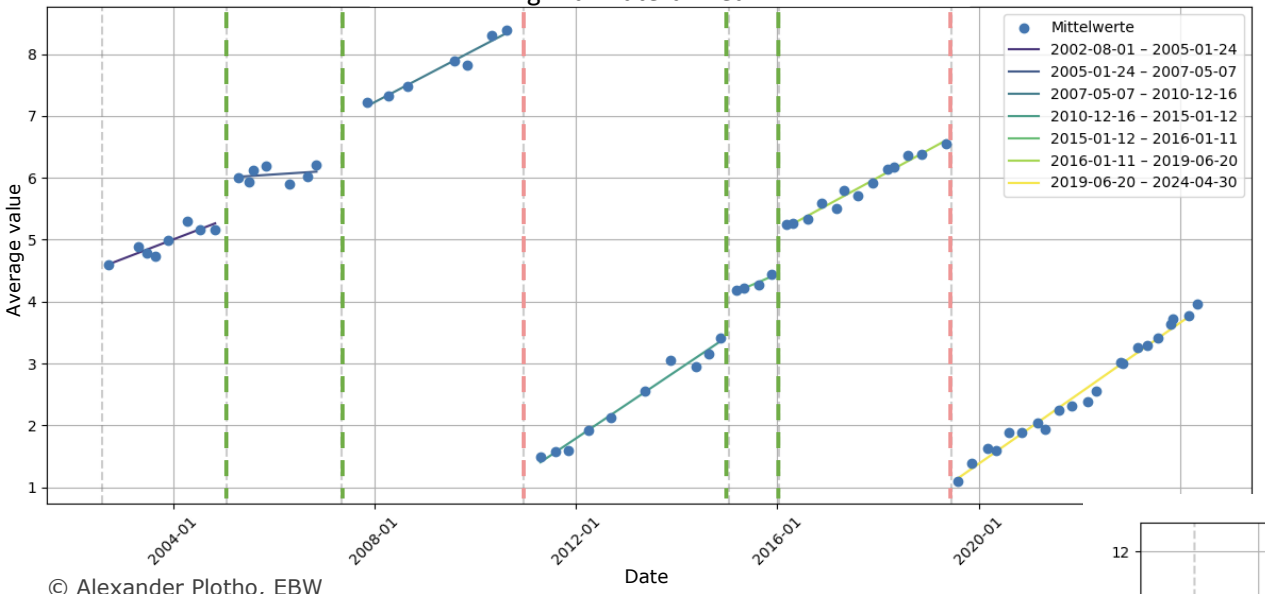
Methodology for maintenance detection

- Data preparation
  - Total average value per curve (sum of vertical and lateral wear, averaged over the entire curve) for each rail
  - Identify incorrect measurements
  - Define outliers
- Identify maintenance measures and rail replacement
  - Due to jumps in the time series of wear signal
  - Positive jumps: maintenance measures
  - Negative jumps: rail exchange

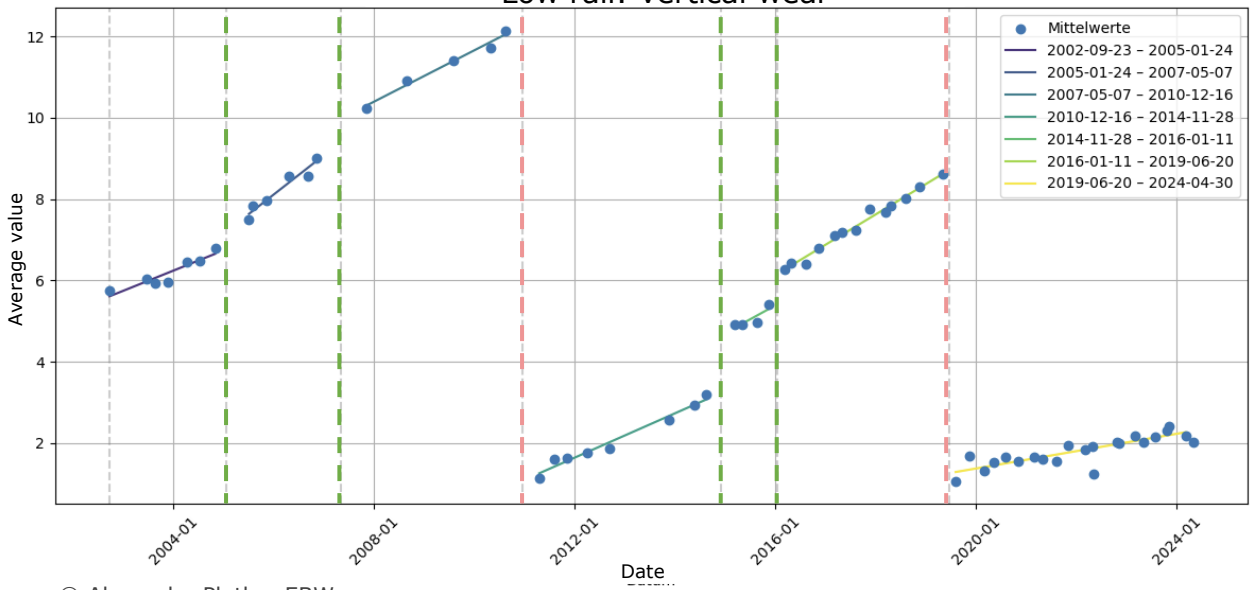


Example: maintenance detection in tight curve

High rail: lateral wear

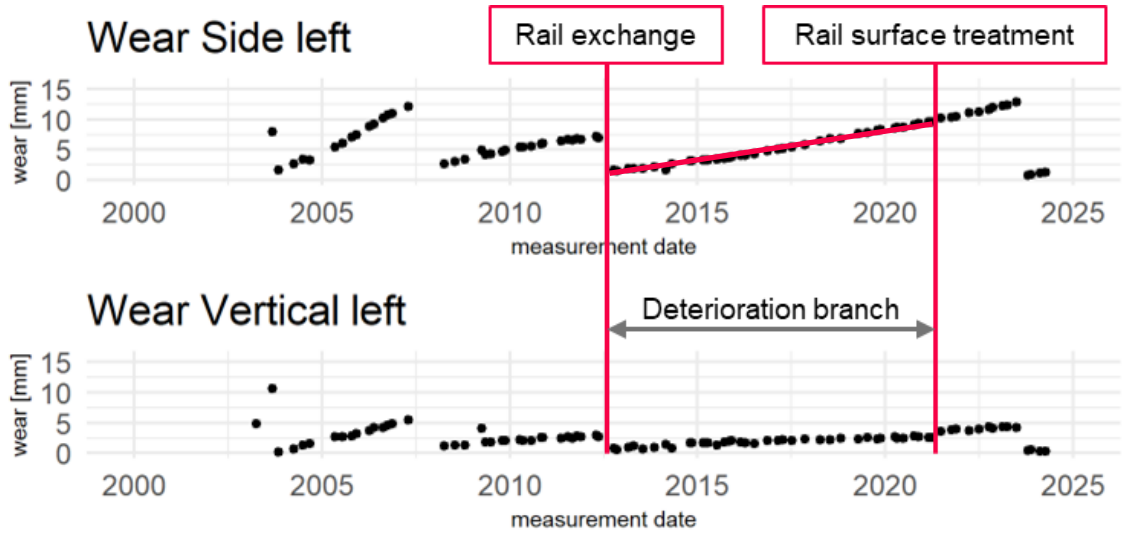


Low rail: vertical wear



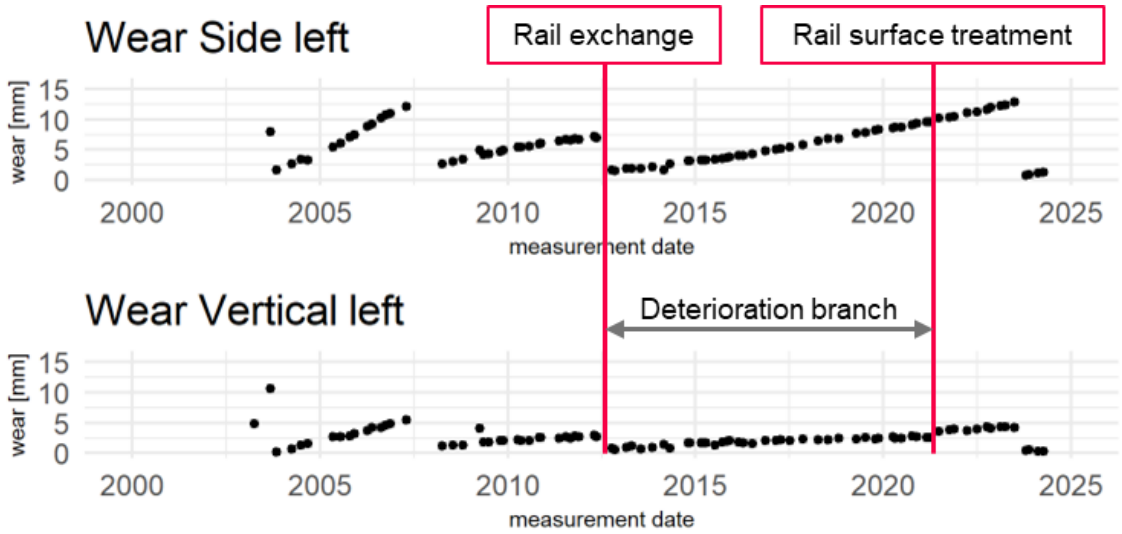
Evaluation of wear data for time series

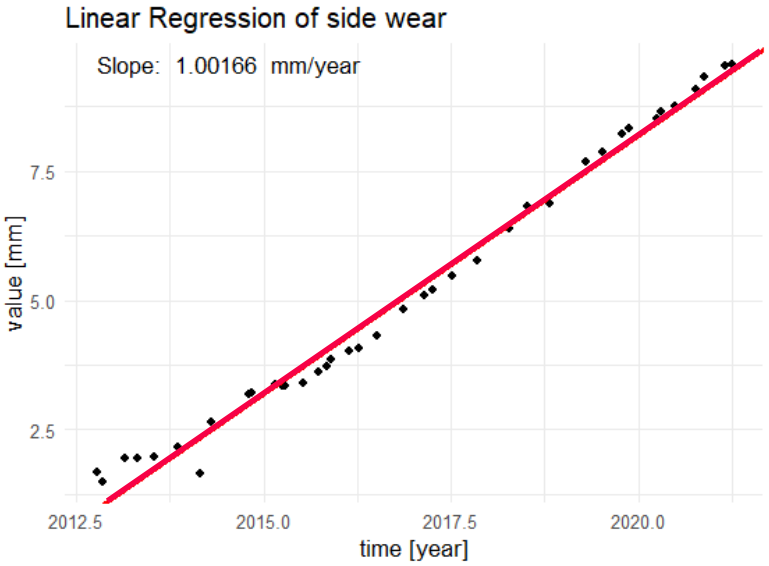
- Rail maintenance actions set limits on deterioration periods



Evaluation of wear data for time series

- Robust linear regression for calculation of wear rate
  - Example: side wear of high rail in curve
- One representative wear rate per deterioration branch
  - Homogenous period with consistent components without disturbance by maintenance

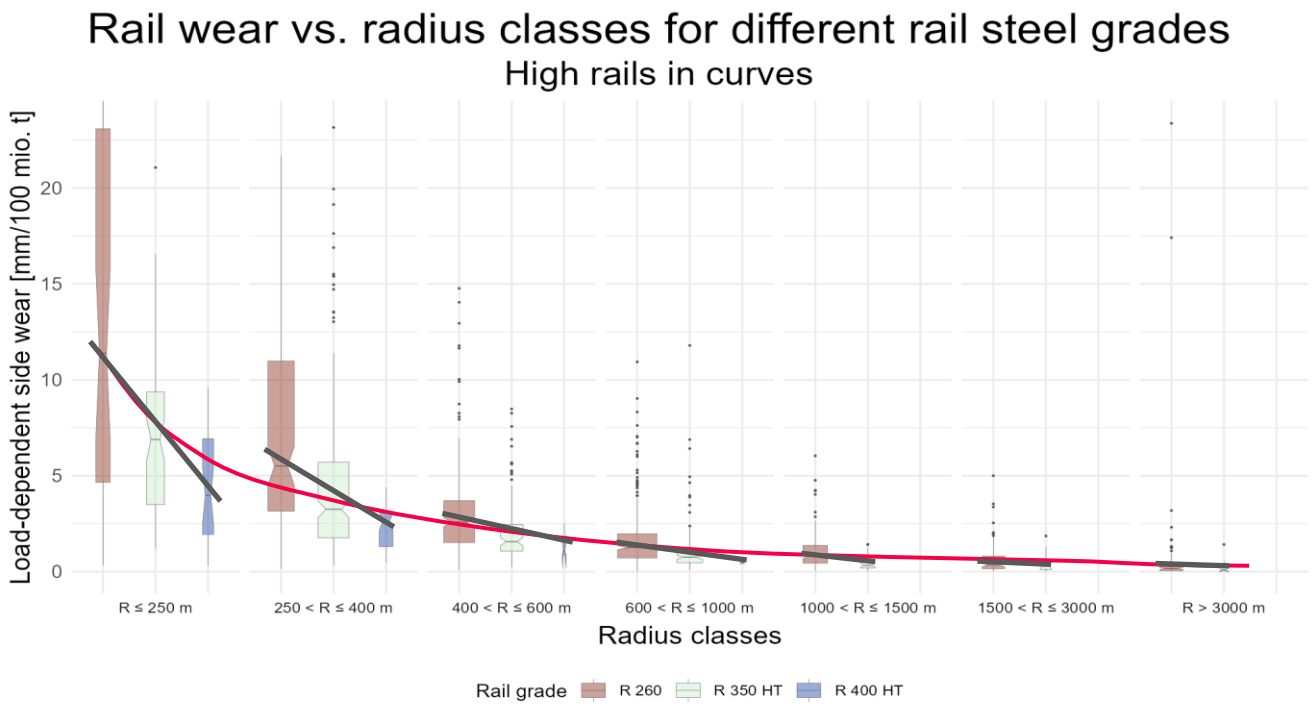




Current status: load-dependent wear

- Radius
- Rail steel grade

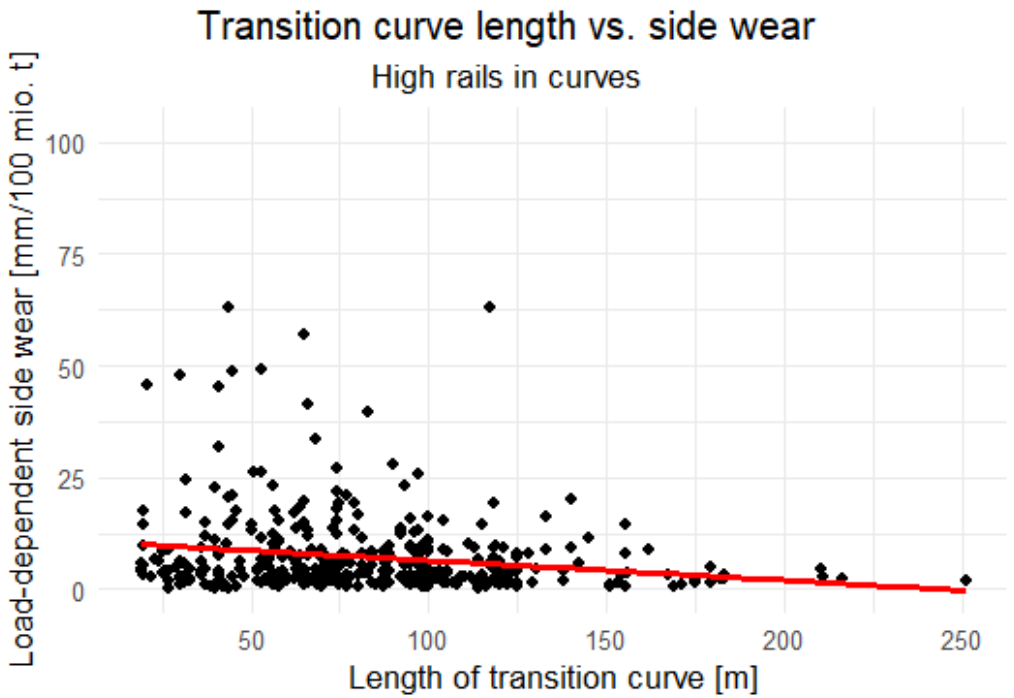
- For the first time: evaluation contains many track sections with various boundary conditions
- Wear per 100 million gross tonnes $\left[\frac{mm}{10^8\ t}\right]$
- Side wear of the high rail as a function of radius class and rail steel grade



Influencing parameters

- Radius
- Rail steel grade
- Transition curve length

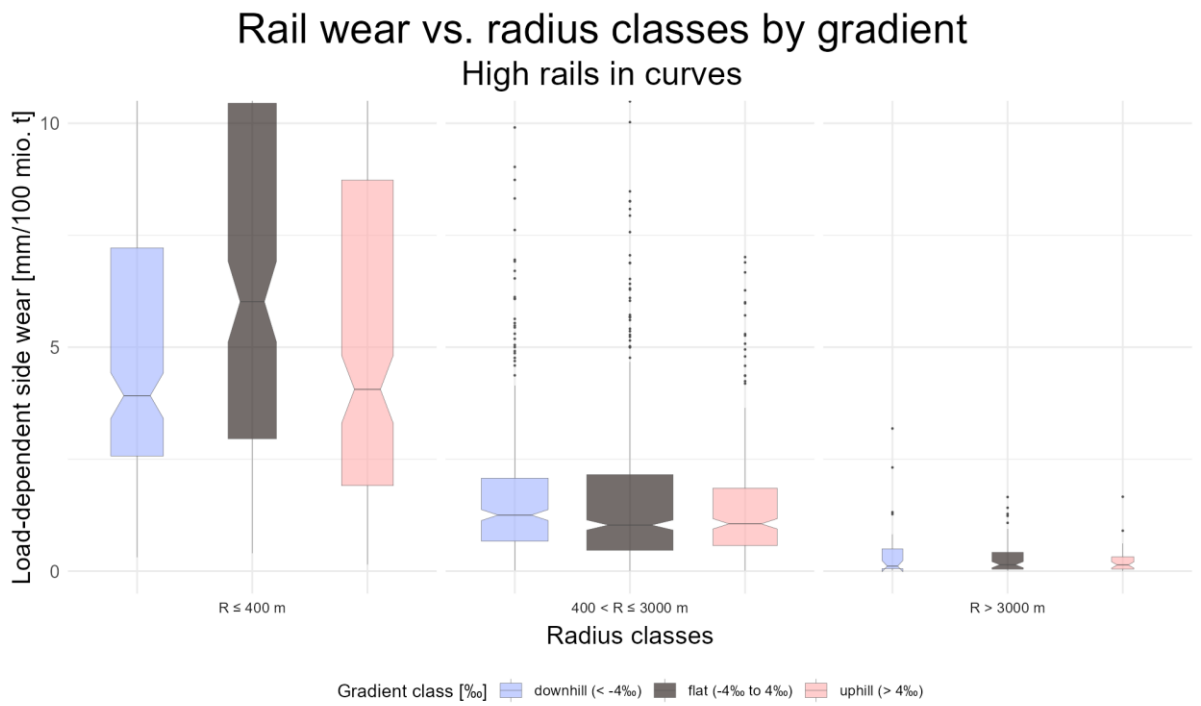
- Transition curve length
  - Higher wear tendency for load-dependent side wear of high rails in curves with short preceding transition curves



Influencing parameters

- Radius
- Rail steel grade
- Transition curve length
- Gradient

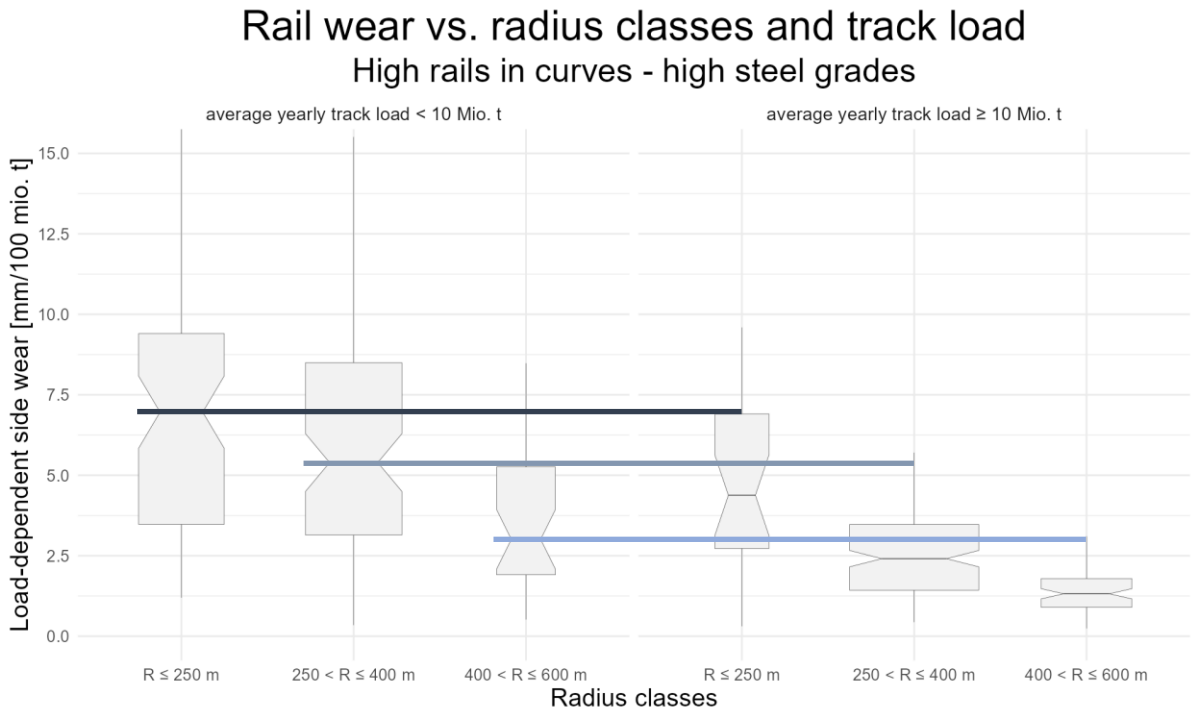
- Gradient
  - Lower wear tendency for load-dependent side wear of high rails in curves with higher gradient
  - Both uphill and downhill



Influencing parameters

- Radius
- Rail steel grade
- Transition curve length
- Gradient
- Track loading

- Track load
  - Low-loaded track sections (<10 mio. tons per year) seem to have **higher** load-dependent wear
  - Curves with radius lower than 600 m, high rails, steel grades R350HT & R400HT



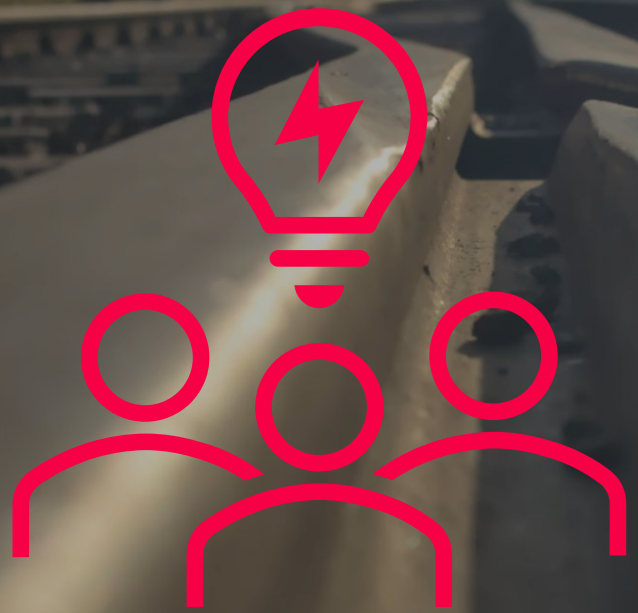
What else?

- Identification of significant influences on rail wear
  - In addition to radius, rail steel grade, etc.

- Extension: Rolling contact fatigue (head checks) – eddy current test data
- Resolve load collective – if possible: vehicle-specific
- ‘Rail damage intensity’: vehicle-specific
  - Parameters for evaluating a vehicle in terms of wear/HCs
- Development of prediction models for wear & HC
- Derivation of predictions for grinding & rail replacement (depending on vehicle & track parameters)

- Development of a stand-alone tool for identifying rail maintenance
  - Time and **location**

- Radius
- Rail steel grade
- Transition curve length
- Gradient
- Track loading
- …



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