Sustainable rail condition management by top of rail friction control: technical and economic aspects

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Overview

- Corrugation Background
- Friction Control for Top of Rail
- Effects of Friction Modifiers on corrugation growth – technical aspects
- Economic aspects of corrugation mitigation
- Conclusions

BACKGROUND ON CORRUGATION

Corrugation Examples

- Commonly found on transit systems
- Multiple types and appearances
- On all types of track

Corrugation Impacts

- Noise and vibration
  - Inside and outside of vehicles
- Potential track and vehicle damage
- Reduced rail life
- Costs to control:
  - Grinding
  - Premature rail replacement
  - Track and vehicle damage

Transit Specific Corrugation Types

Pinned-Pinned	P2 Resonance	Rutting
Rail oscillation pinned by ties (nodes)	Second oscillation of unsprung mass of vehicle. (Vehicle "bouncing" on track)	Roll–slip oscillation associated with differential tangential force between low and high rail wheels
400-1200 Hz	50-100 Hz	250-400 Hz

Train Speed

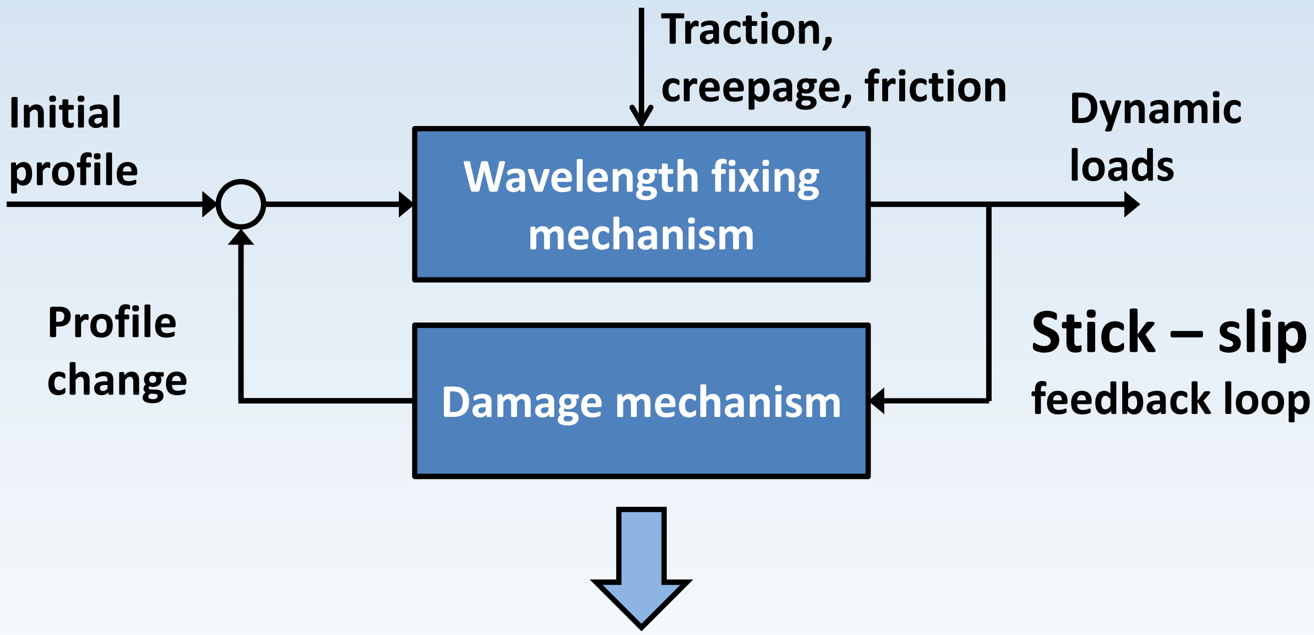
Corrugation wavelength

$$\lambda = \frac{v}{f}$$

Corrugation frequency

Corrugation frequency will indicate the underlying mechanism

Components of Corrugation Formation



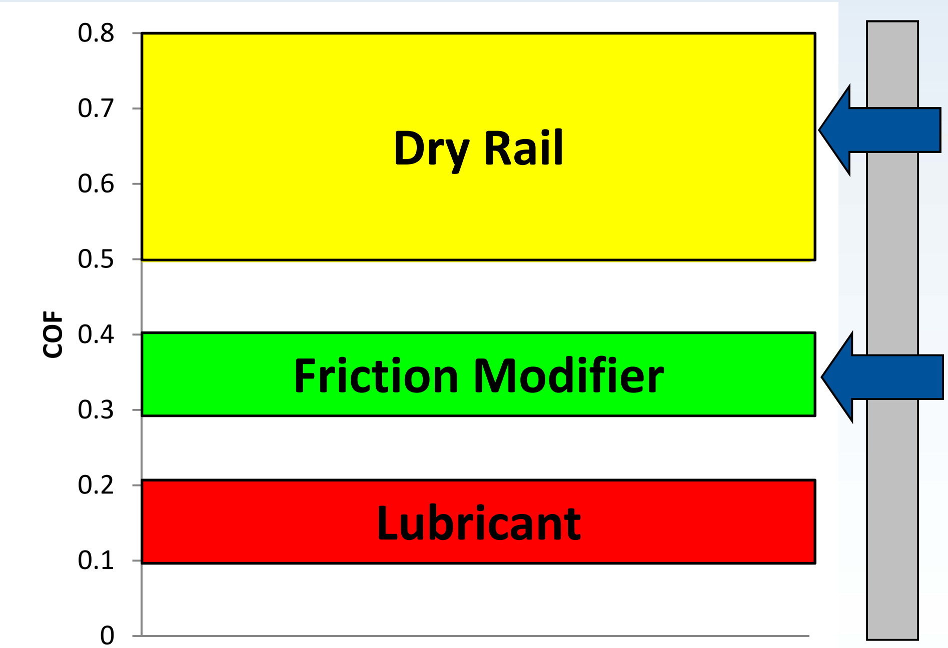
- **Wear**
- Plastic flow
- Contact Fatigue

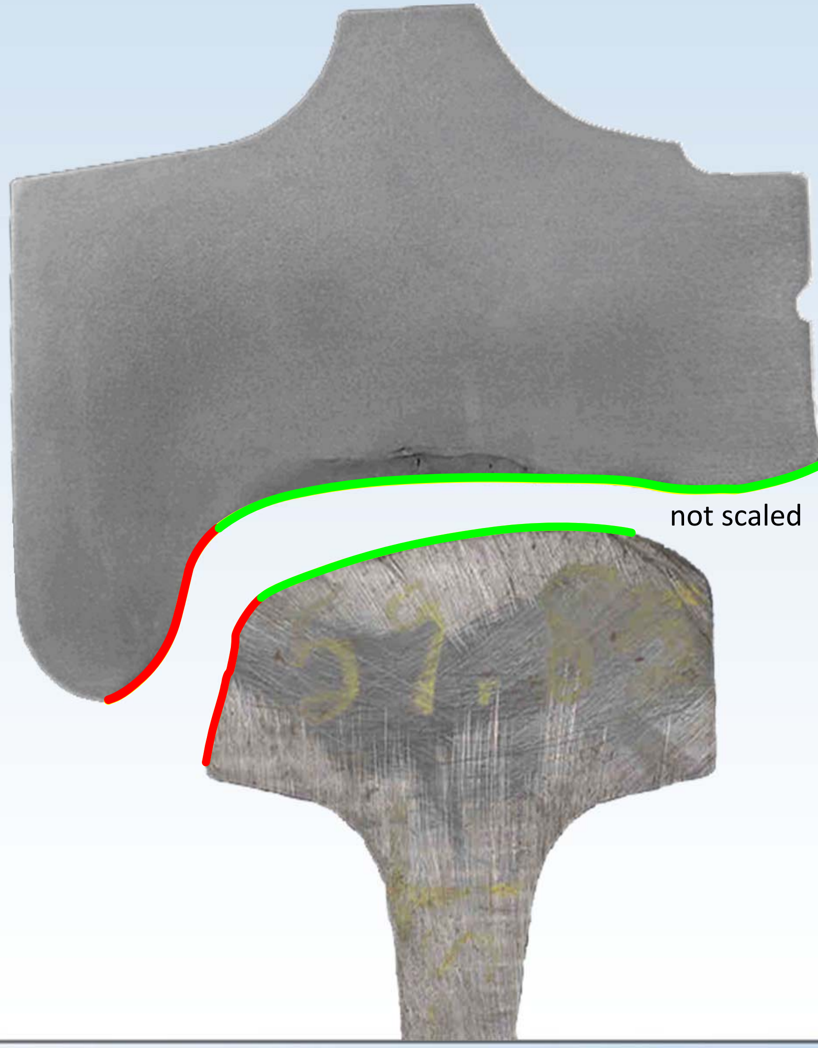
(Dr. S. Grassie, Dr. J. Kalousek)

FRICTION CONTROL FOR TOP OF RAIL

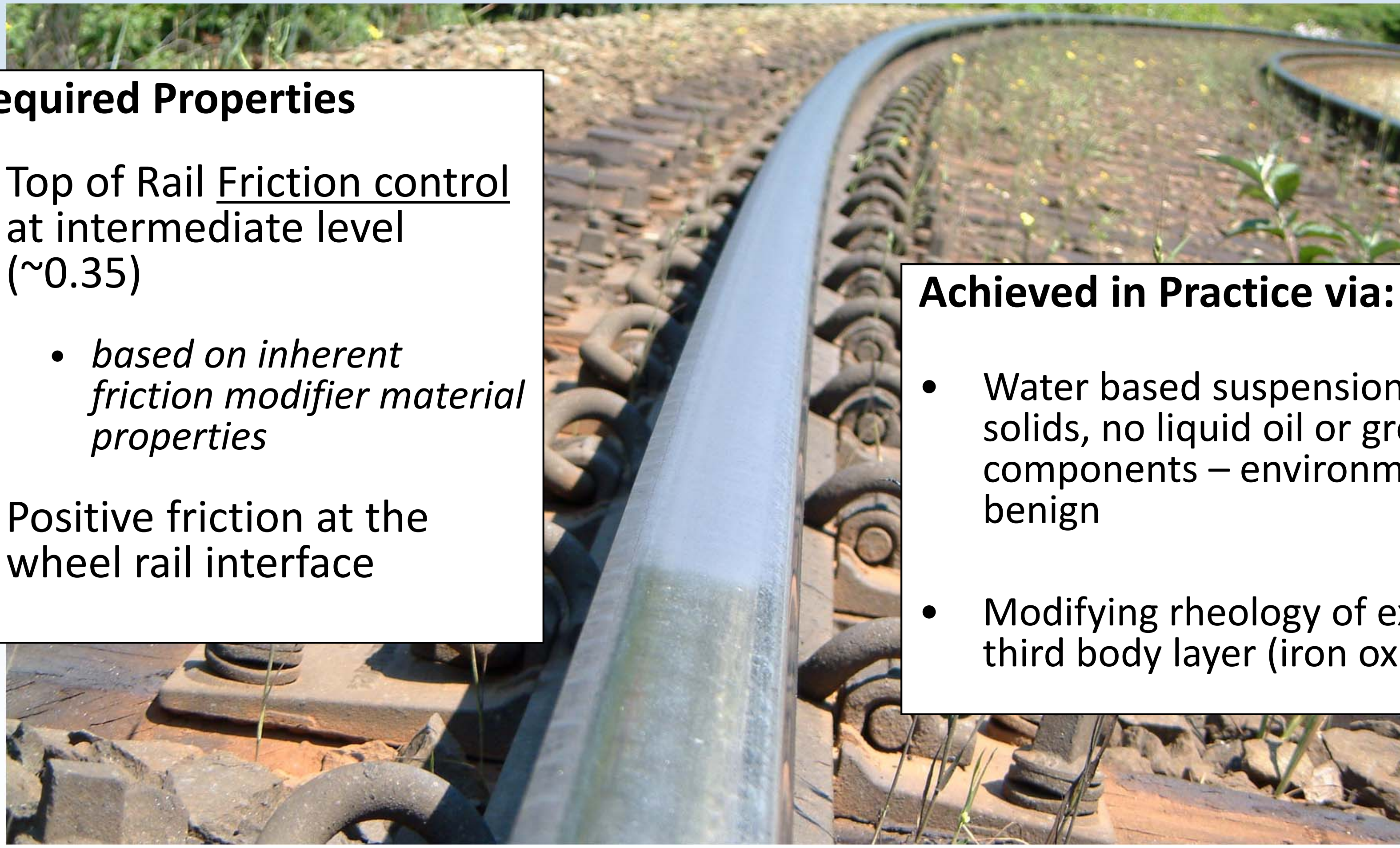
The Proper Material for the Proper Surface

- **Lubrication reduces** friction to a **minimum** level
- **TOR Friction Control reduces** friction to a **controlled** level





KELTRACK®
Top of Rail Friction Modifier



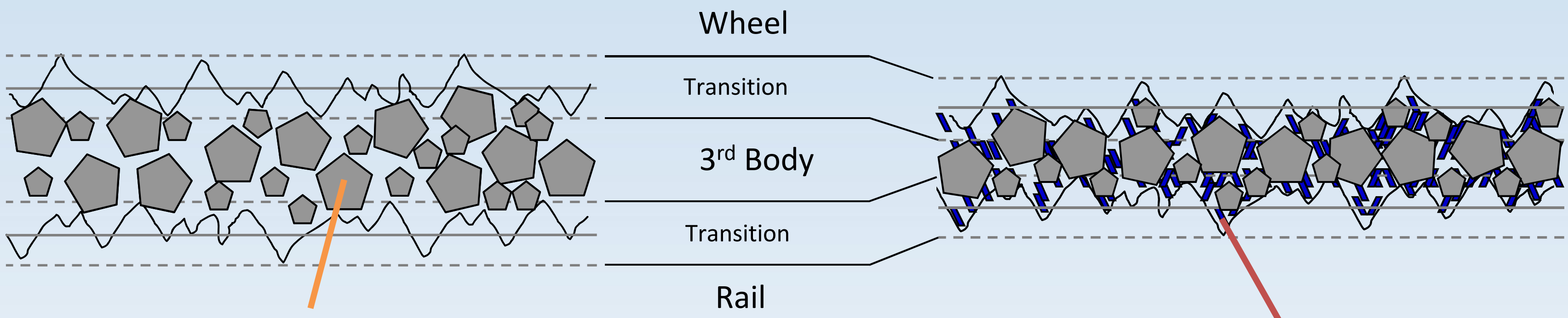
Required Properties

- Top of Rail Friction control at intermediate level (~0.35)
    - *based on inherent friction modifier material properties*
- Positive friction at the wheel rail interface

Achieved in Practice via:

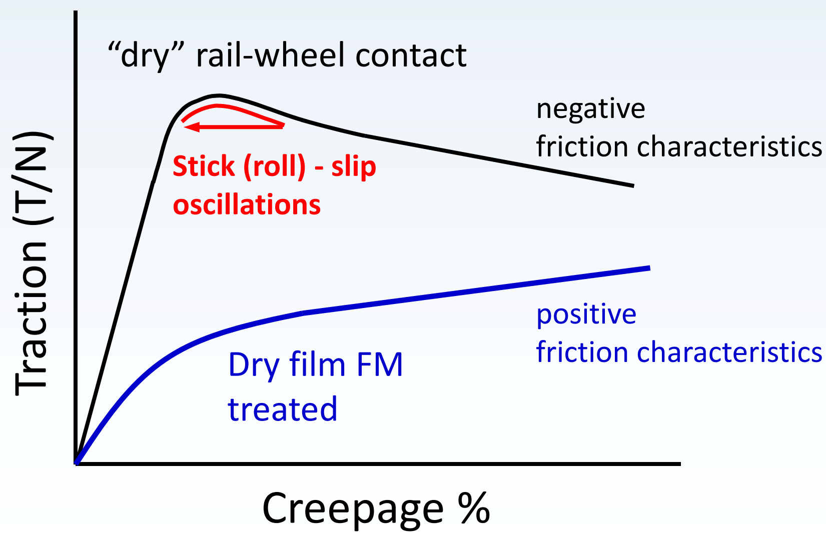
- Water based suspension of dry solids, no liquid oil or grease components – environmentally benign
- Modifying rheology of existing third body layer (iron oxides)

Friction Modifier: Positive Friction



Brittle "High Hardness" Wear Particles (Fe_3O_4)

Pliable "Soft" FM Particles



Influence of Friction Modifier on Corrugation

- **Reduced absolute friction levels** on the rail head (without compromising traction / braking) expected to reduce wear component of corrugation mechanism

- **Positive friction characteristics of interfacial layer -** reduction of roll-slip oscillations associated with wavelength fixing / initiation component of rutting corrugation mechanism

WHEEL RAIL APPROACHES TO CORRUGATION GROWTH

Corrugation Control

- Grinding / wheel rail profiles
- Hard rails
- Friction Management

Grinding and Corrugation

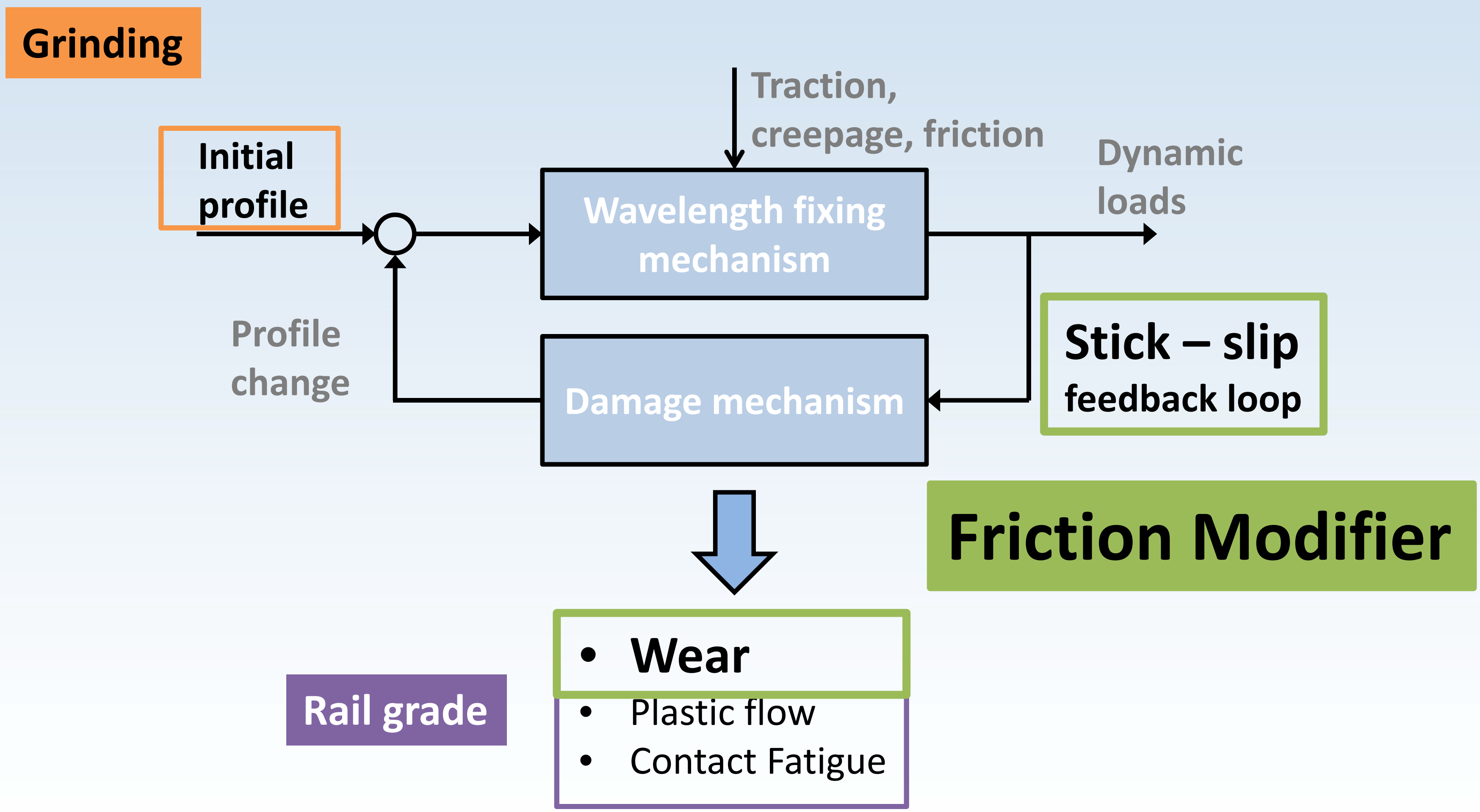
- Will remove corrugation if applied correctly
- Adjust profiles and improve steering
- Will primarily treat the symptoms

Premium Rails and Corrugation

- With increasing rail hardness reduced formation of corrugation - wear resistance
- Rails cannot address the stick-slip oscillation mechanism
- Rail exchange only feasible when existing rail close to end of life

Source: A. Jörg, R. Stock: The Heat Treated Premium Rail Grade R400HT – High Strength Rail Steels in Austria and Switzerland, ZEV Rail 136 (2012) Innotrans Special Edition, p72-79

Friction Modifier and Corrugation



(Dr. S. Grassie, Dr. J. Kalousek)

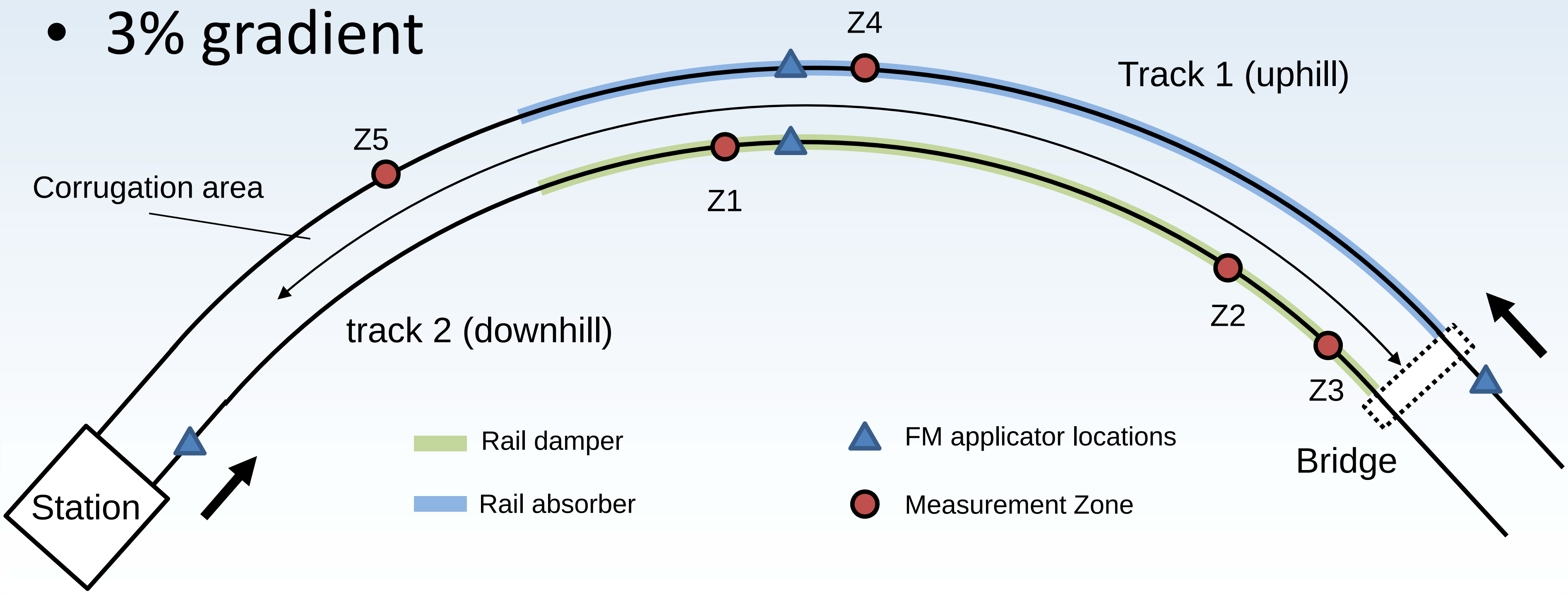
KELTRACK® Application Systems

- Wayside Application

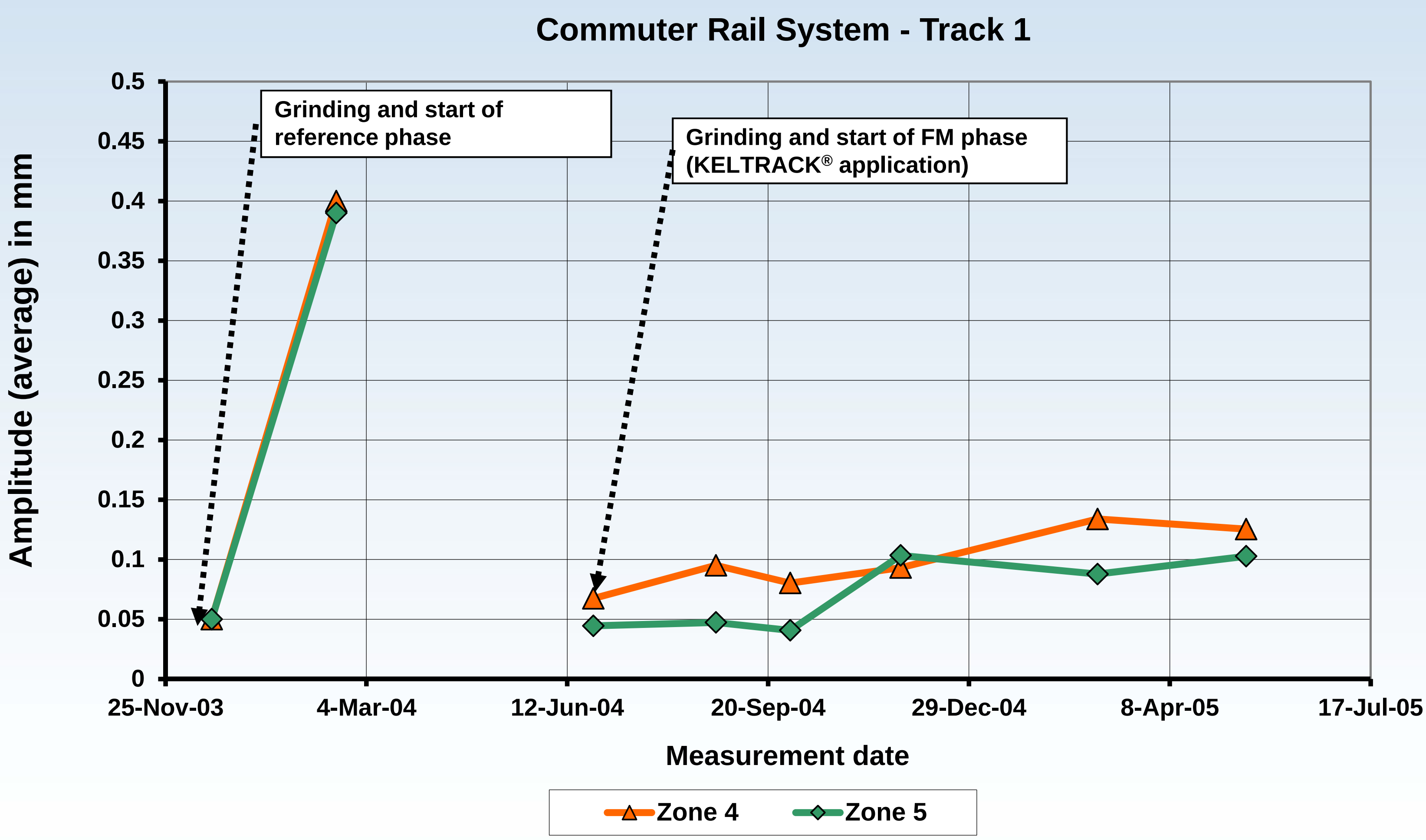
- Onboard Application

Track Test Example

- Commuter Rail
- Curve radius: 227m, curve length: 480m
- Ballast / concrete sleepers
- 3% gradient



Results



Commuter Rail System - Track 1
Amplitude (average) in mm
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Grinding and start of reference phase
Grinding and start of FM phase (KELTRACK® application)
25-Nov-03
4-Mar-04
12-Jun-04
20-Sep-04
29-Dec-04
8-Apr-05
17-Jul-05
Measurement date
Zone 4
Zone 5

Corrugation comparison

Improvement factor of 27

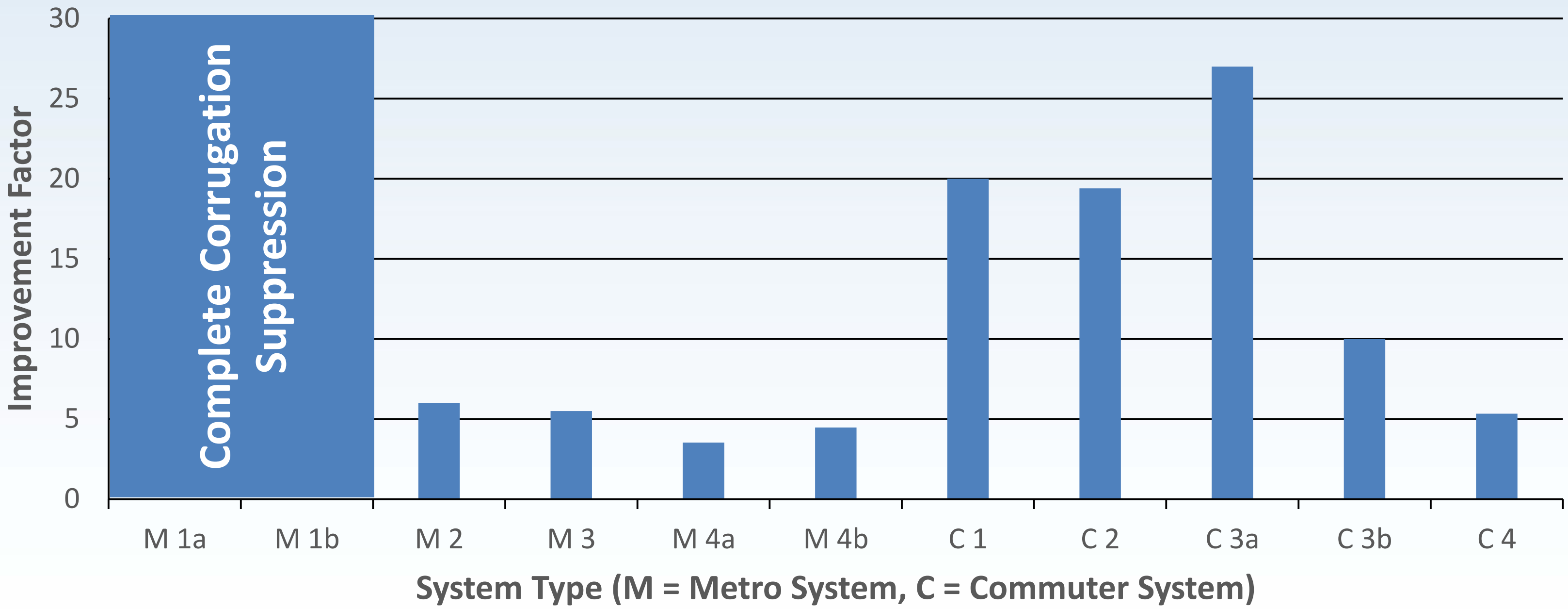
(based on corrugation growth per 30 days)

Reference phase – 30 days after grinding

FM phase – 280 days after grinding

Overview over All KELTRACK® Track Tests

- Average corrugation improvement factor: 11
- Variability: complete suppression to factor 4



ECONOMIC ASPECTS

Economic Factors

- Noise and Vibration
- Damage of track components
- Grinding
- Friction Management

Noise and Vibration

- Difficult to indicate direct cost impact
- Legislative noise regulations
- Upset residents in neighbourhood
  - Local politician in the neighbourhood?
  - Lawsuits?
  - Health Impact?
- Vibration might cause some track / vehicle damage
- Impact on highly vibration sensitive public buildings

Damage of Track Components

- Vibration
  - Ballast degradation
  - Sleeper damage
  - Clip breakage
- Replacement Costs
  - Material costs
  - Labour costs
  - Track closure costs

Grinding Costs

- Machine availability
- Machine costs per shift
- Available operating windows
- Related maintenance activities
  - Removal and installation of track equipment
- Safety considerations / restrictions
- Track closures

Friction Management

- Installation costs
- Consumables costs
- Maintenance (filling, repair)
  - In house
  - Service contract

Hypothetical Case: Assumptions

- Corrugation Trial at Transit A showed an improvement factor of 10 by FM application.
- Grinding interval of 6 months (contracted)
  - 2 grinding campaigns per year

Hypothetical Case: Maintenance Window

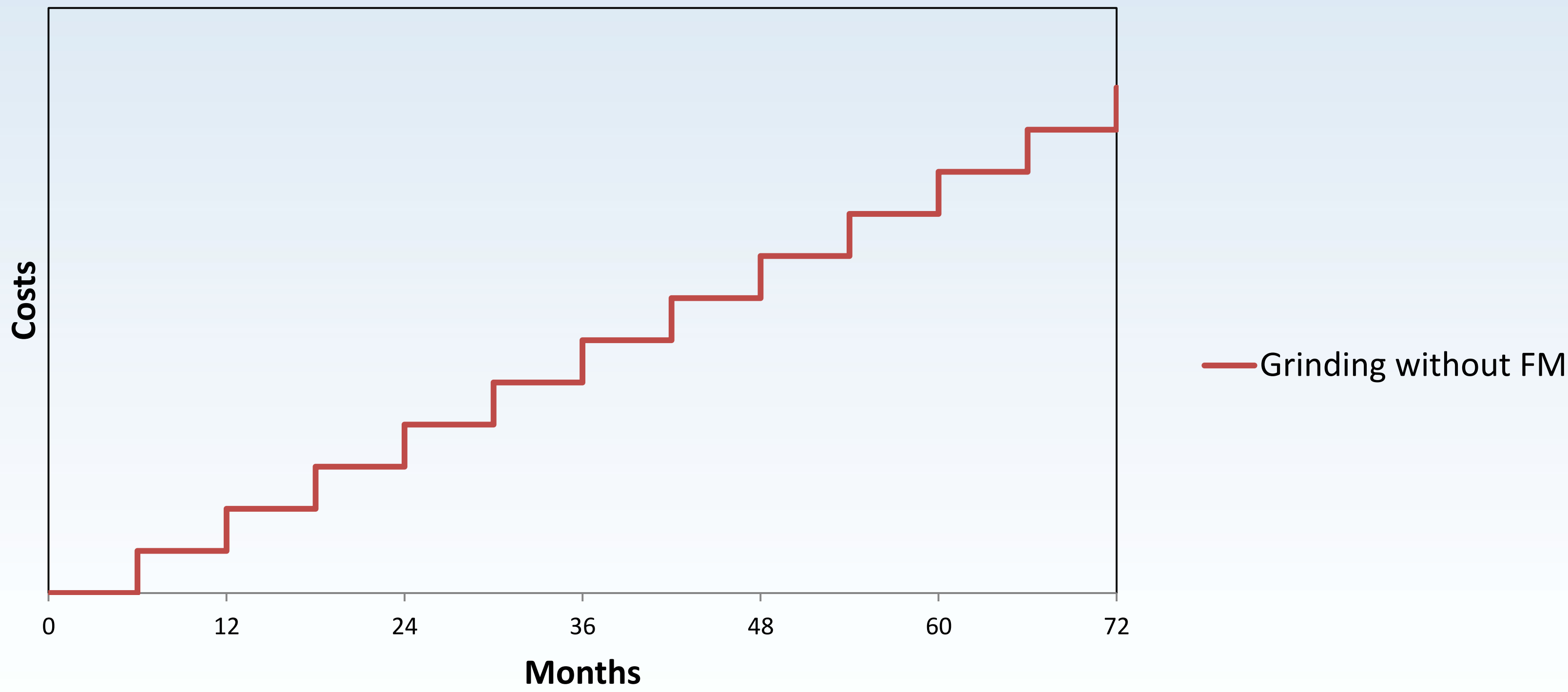
- No Operation between 1am and 5am
- Grinding Window 1:30am – 4:30 am
- Full time operational between Saturday 5am and Monday 1am
  - No maintenance on the week-ends
- 5 shifts per week each 3h maximum

Hypothetical Case: Further Assumptions

- x% of track have corrugation problems
- 20 grinding shifts to treat these x% per campaign
  - Costs per shift include everything
- 20 FM applicators to effectively treat these x%
- Typical application settings, typical axle count
- Conservative numbers for costs
  - Grinding costs on lower end
  - Consumable costs factor in maintenance (percentage)

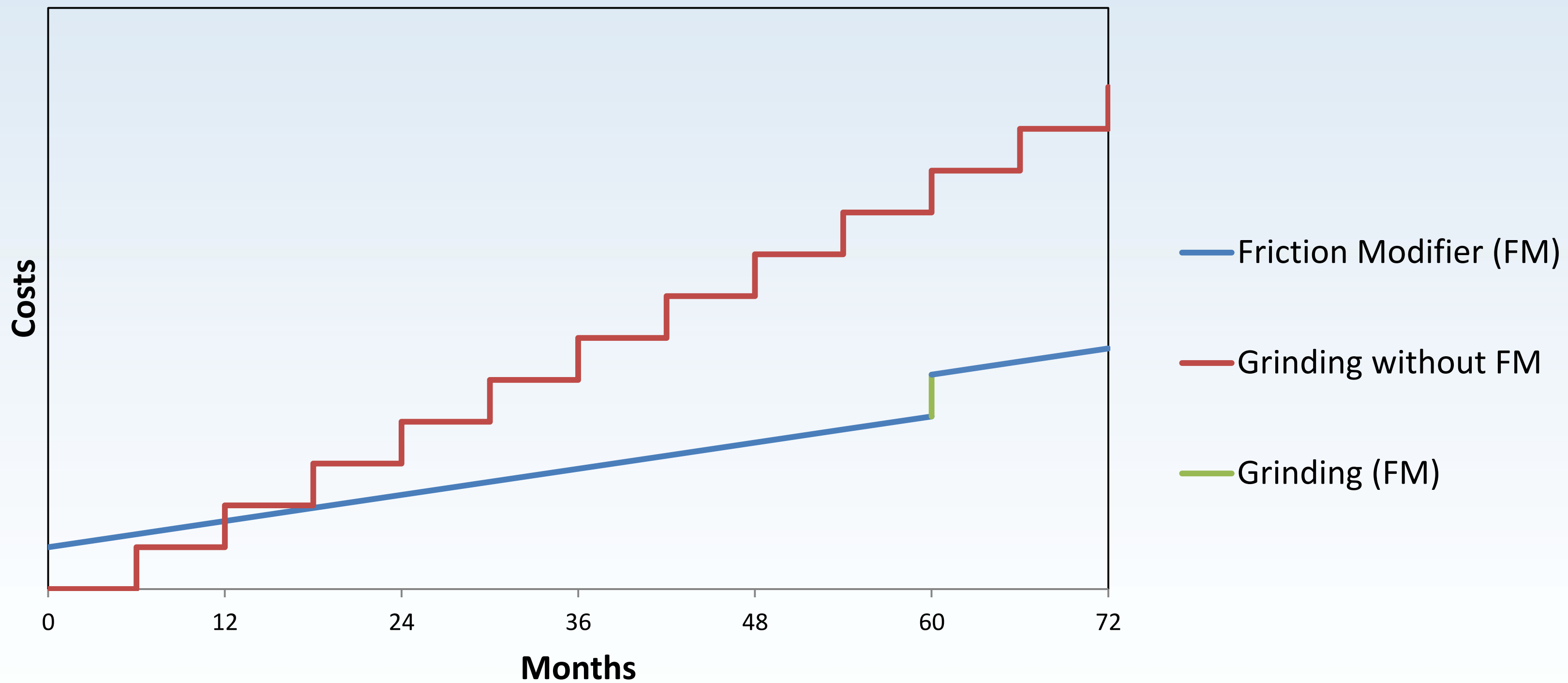
Hypothetical Case: Cost development

- Based on assumptions for example case



Hypothetical Case: Cost development

- Cost saving with TOR-FM possible



Simplified Payback Calculation

- C_{GR}: Grinding Cost per year [1/year]
  - *Grinding cost per shift* x *No. shifts* x *No. of campaigns per year*

Simplified Payback Calculation

- C_{GR}: Grinding Cost (without FM) [1/year]
- C_{CAP}: Investment Cost for FM equipment

Simplified Payback Calculation

- C_{GR}: Grinding Cost (without FM) [1/year]
- C_{CAP}: Investment Cost for FM equipment
- C_{FM}: Friction Management Costs [1/year]
  - Consumables Cost + Grinding cost with FM
  - Consumables Costs:
    - *No. FM units* x *application settings in gal / axle* x *No. axles per year* x *FM costs per gal (incl. maintenance)*
  - Grinding cost per year for FM:
    - C_{GR} / Improvement Factor by FM

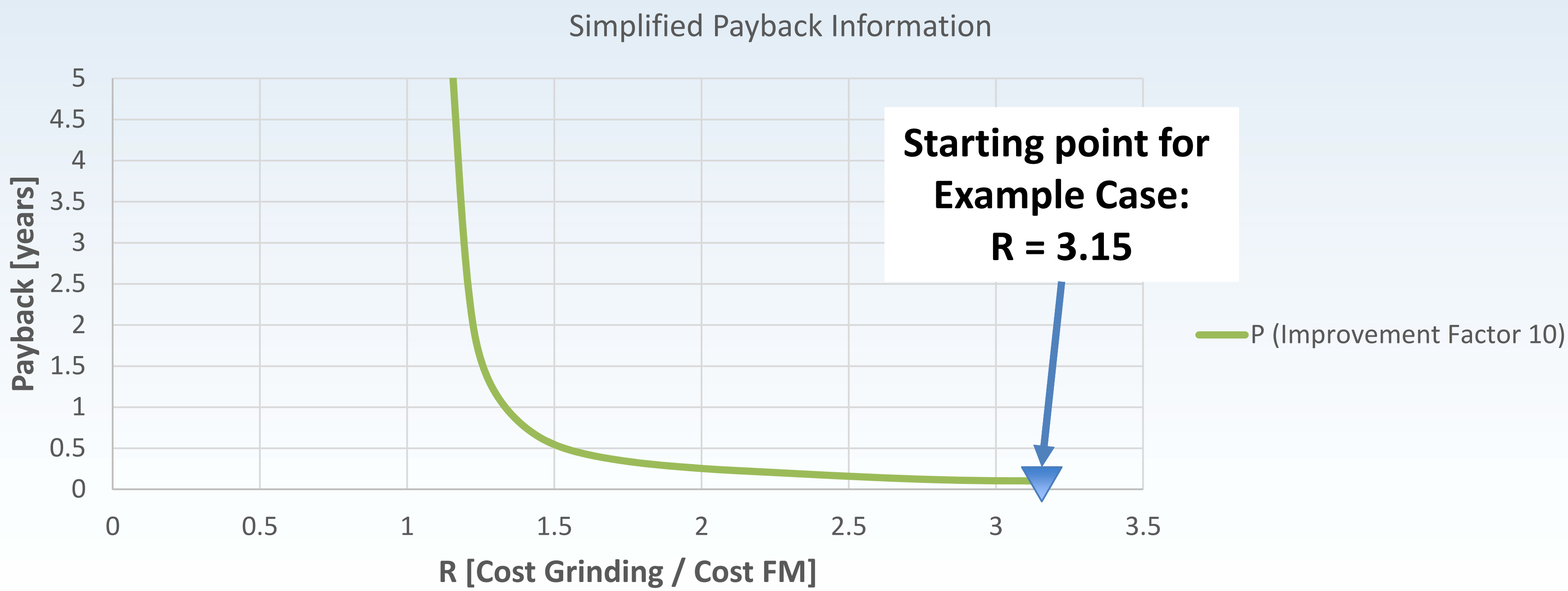
Simplified Payback Calculation

- C_{GR}: Grinding Cost (without FM) [1/year]
- C_{CAP}: Investment Cost for FM equipment
- C_{FM}: Friction Management Costs [1/year]

- **R**: C_{GR} / C_{FM} ... Cost Ratio grinding vs. FM
- **P**: $C_{CAP} / (C_{GR} – C_{FM})$ ... Payback [years]

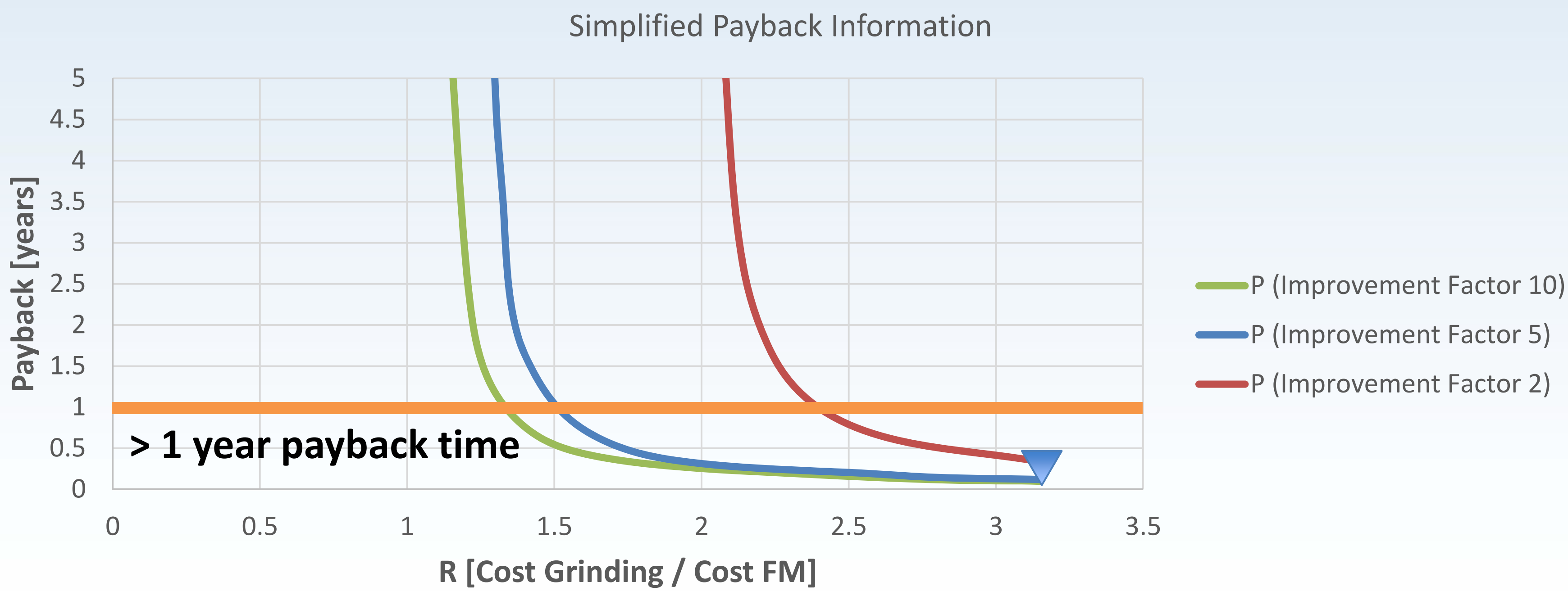
Example Case: Payback Diagram

- Payback in [years] over cost ratio for given improvement factor by FM



Example Case: Payback Diagram

- Excellent payback time also for lower improvement factors possible



Conclusions

- KELTRACK® Friction Modifier can successfully mitigate rutting corrugation development by impacting both relevant development factors
- Short pitch corrugation growth rate can be reduced on average by factor 11 by TOR-FM
- Clear economic benefits
  - Payback within a year or less even for low reduction factors for the assumed case

Thank You for Your Attention

LBFoster
Rail Technologies

Source: P.T. Torstensson, Charmec, Sweden