HEAVY HAUL SEMINAR

Antonio Merheb

Vice-Chair of the **International Heavy Haul Association (IHHA)** and Consultant at **MRS Logistics**

JUNE 10-12, 2025

WRI2025HH

Extending Rail Life in Heavy Haul Railroads:

The Role of Elastic Components in Track Performance

Antonio Merheb
MRS Logistics

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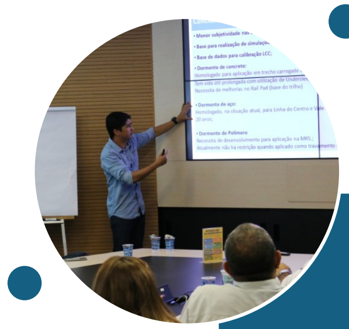
My journey (18 + years…)

Career development

- Be resilient
- Embrace adaptation
- Share lessons learned
- View mistakes as opportunities to learn

International Heavy Haul Association
Railroad industry

MRS Logistics
Railroad industry



University of Sao Paulo
Railroad research

Norsk Hydro
Aluminum industry

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About MRS Logistics

Railroad operating in a region that generates nearly half of Brazil's GDP.

- Connecting the key states of Minas Gerais, Rio de Janeiro, and São Paulo.
- Direct access to Brazil's main ports
- Track network: 1.643 km
- Typical train: 2 locomotives and 136 wagons

20.000 WAGONS

680 LOCOMOTIVES

20% OF ALL BRAZILIAN EXPORTS

Heavy Haul	8 products
General cargo	85 products

+ 80 Terminals

Chemical

Iron Ore

Pig Iron

Soy bean

Container

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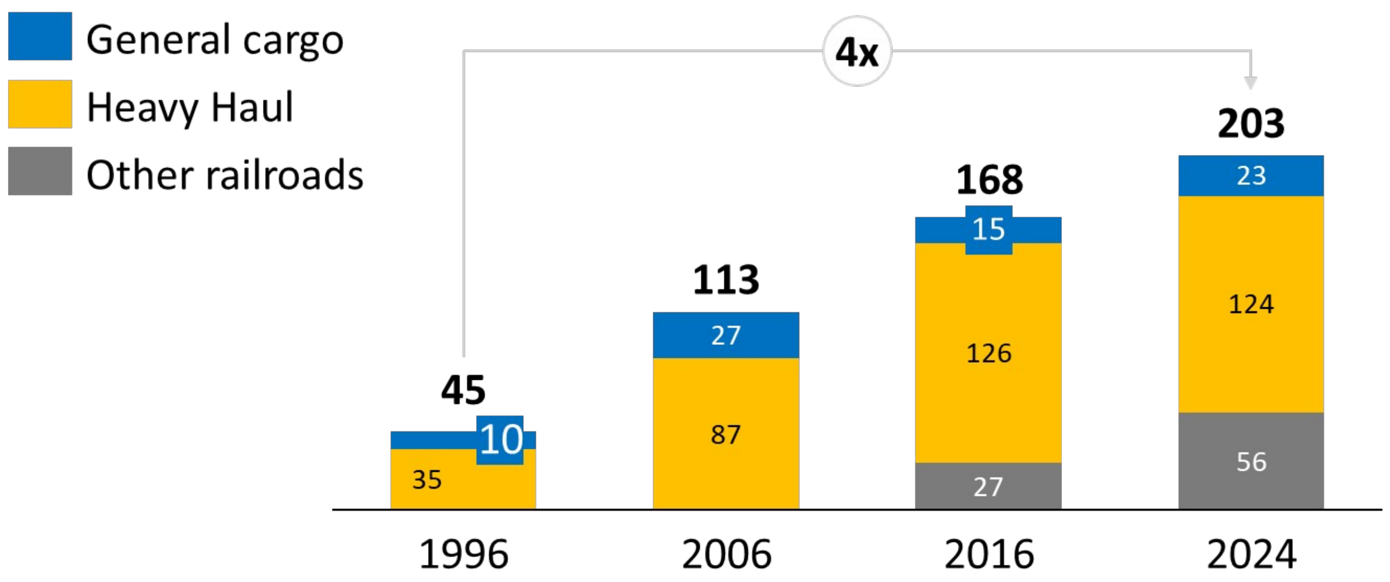
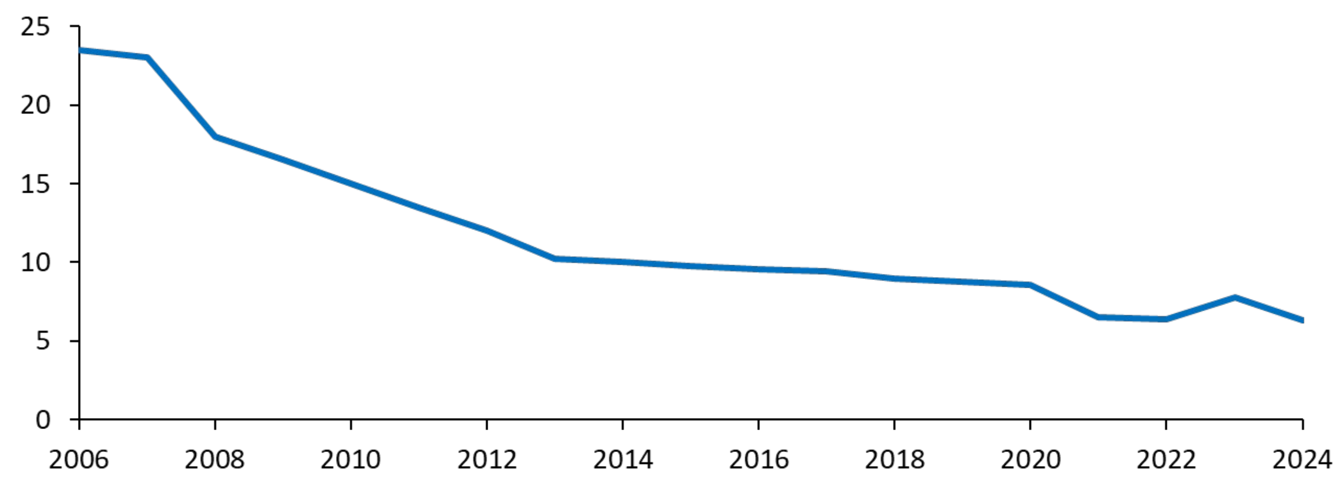
About MRS Logistics

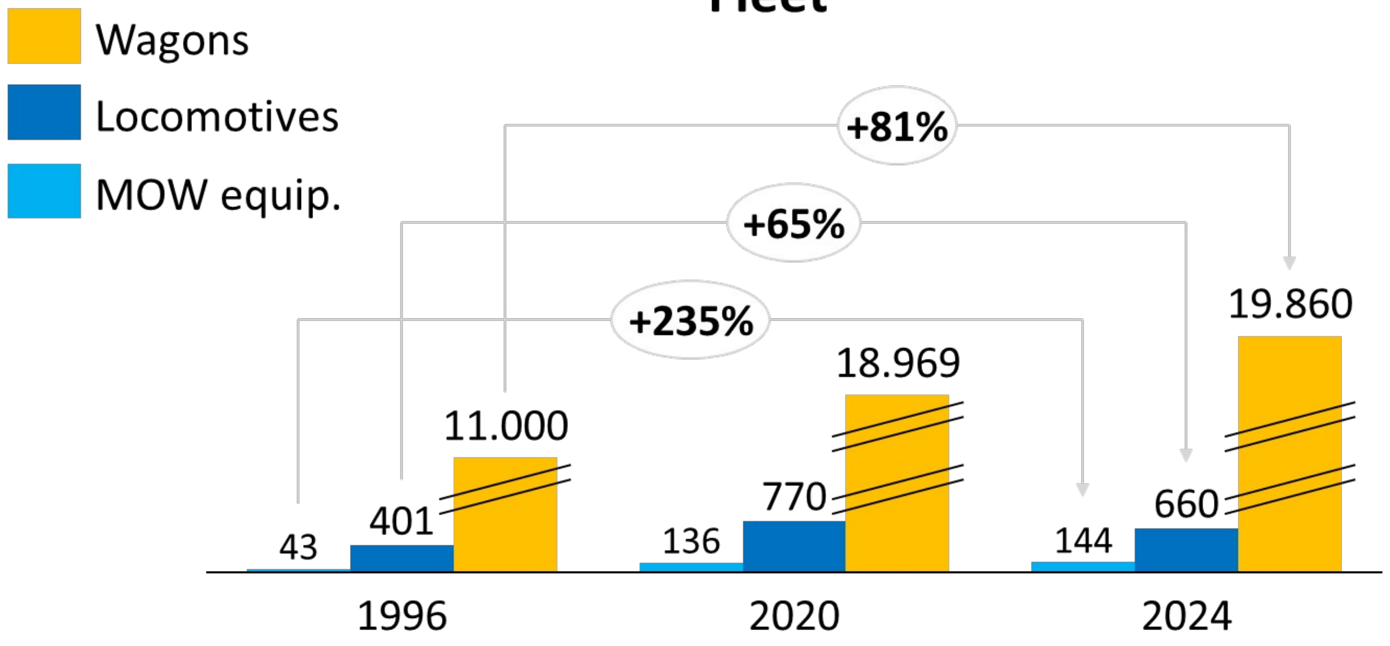
Total volume carried (millions of tonnes)



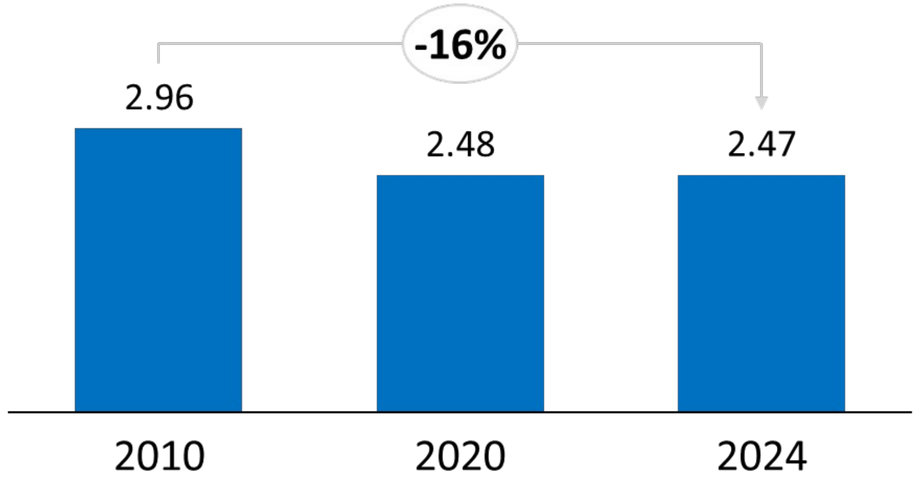
Number of Accidents per millions of trains



Fleet



Energy Efficiency (liters/kTKB)



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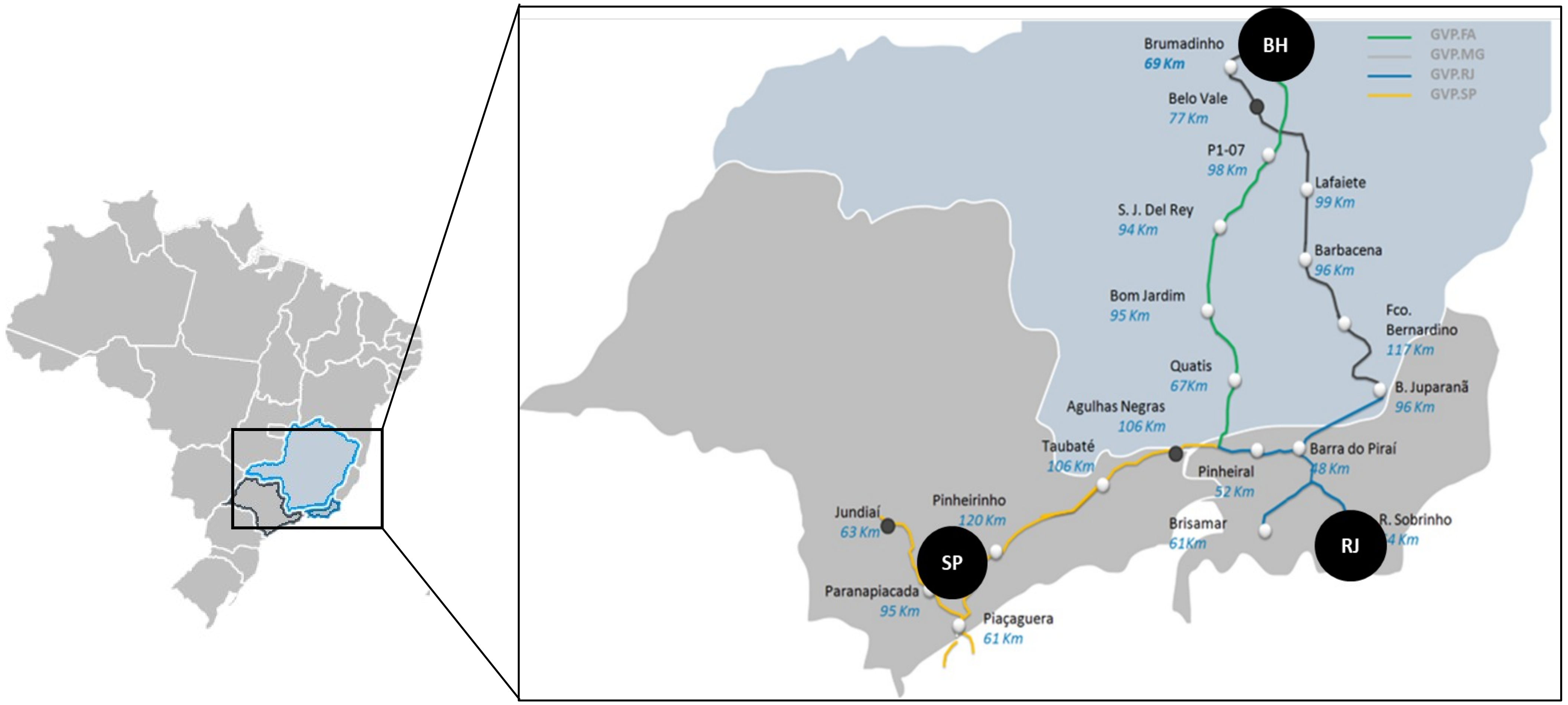
Operational challenges



Within the most populated region: 80 million people

180 MGT
Max. Grade 1,2%
Radius min. 3°
Built: 1989

200 MGT
Max. grade 2,2%
Radius min. 9°
Built: 1880

12 MGT
Max. grade 11,8%
Radius min. 8°
Built: 1960

4.200	5.814	1.000	631	141
Culverts	Cuts and Fills	Crossings	Railway bridges	Tunnels

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Challenges and current projects

Operations

- Duplicate the train size to 272 wagon
- Increase speed in 25%
- Increase the axle loads: 32,5 to 36 tonnes

Track

- Implement predictive maintenance
- Track renewal program
  - Ballast Cleaning, Drainage Recovery, and 1M+ Tie Replacements

Rolling stock

- Acquisition of new generation of locomotives
- Advance in hybrid and electric systems
- Adoption of AI-Based Inspection and Real-Time Asset Management

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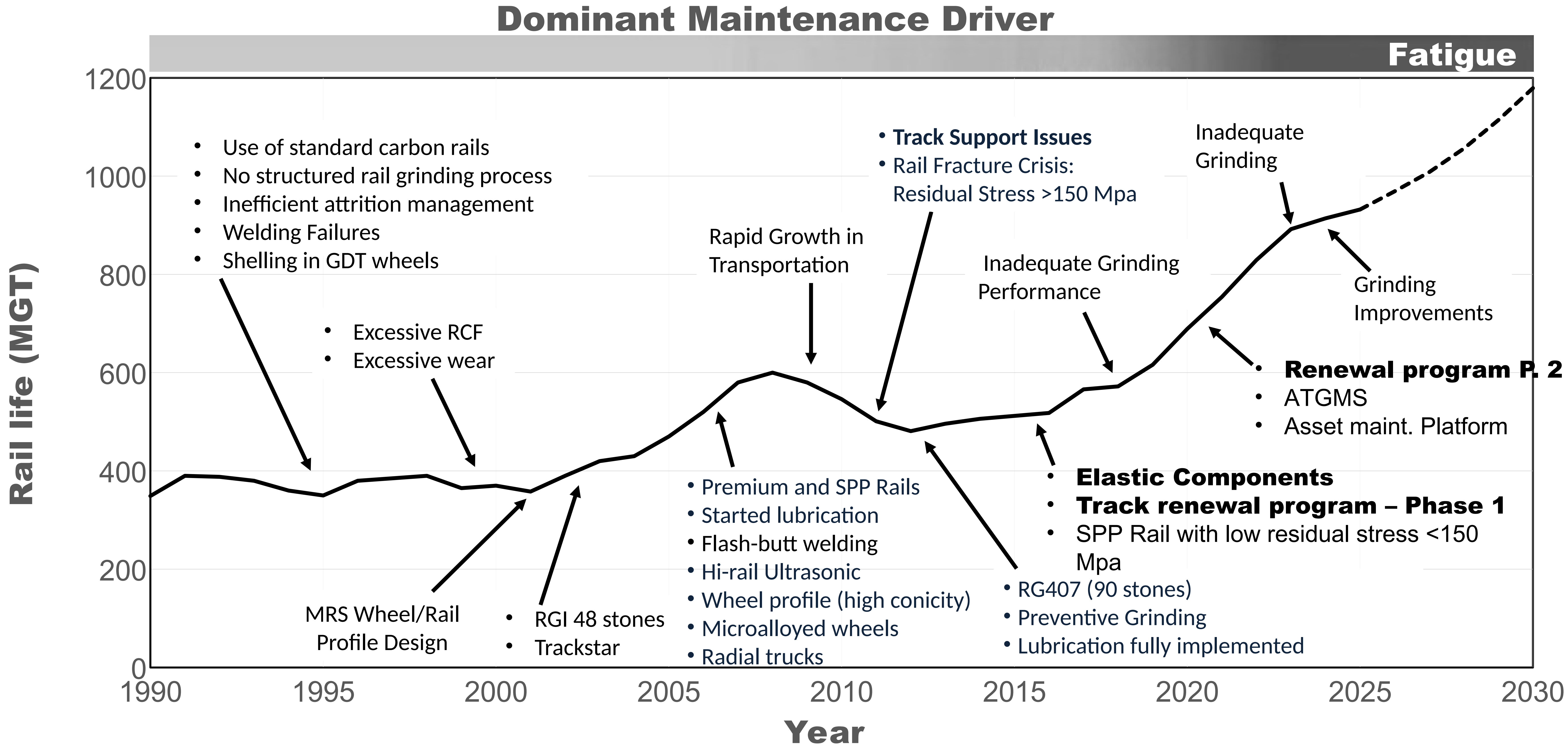
Rail Life (1996–Present): Key Events



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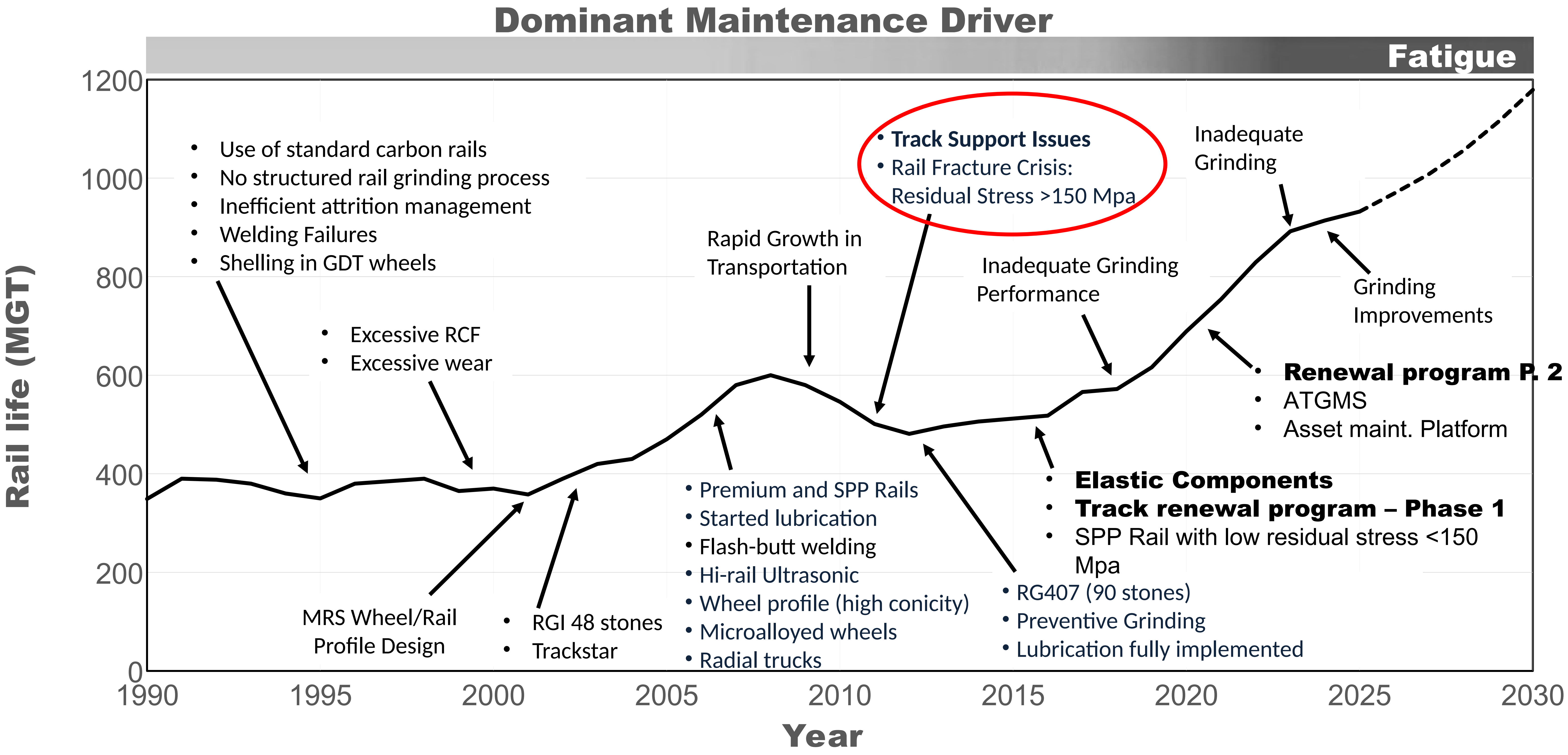
Rail Life (1996–Present): Key Events



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MRS substructure condition

Drainage problems

Recurrent geometry defects

Stiffness seasonal variation

Hight Ballast

LIFE CYCLE

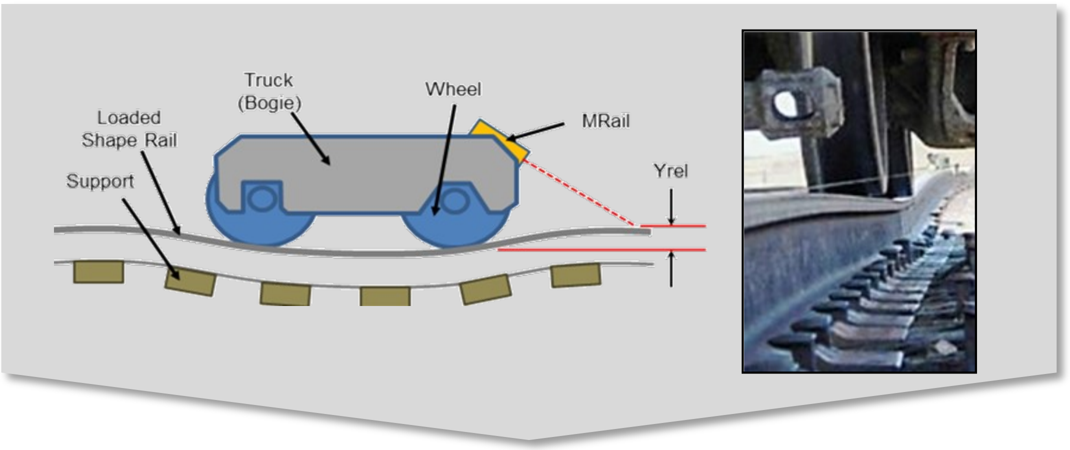
Decrease the components life cyce

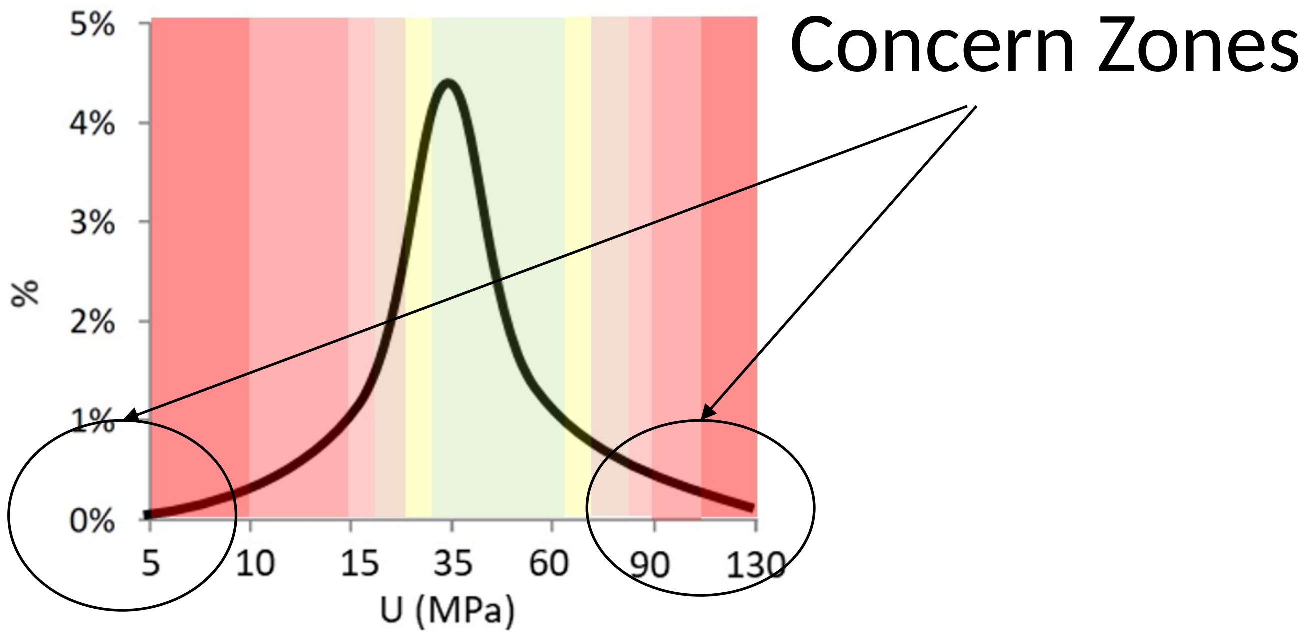
Maintenance and operational costs

Less track availability

Substructure investigation

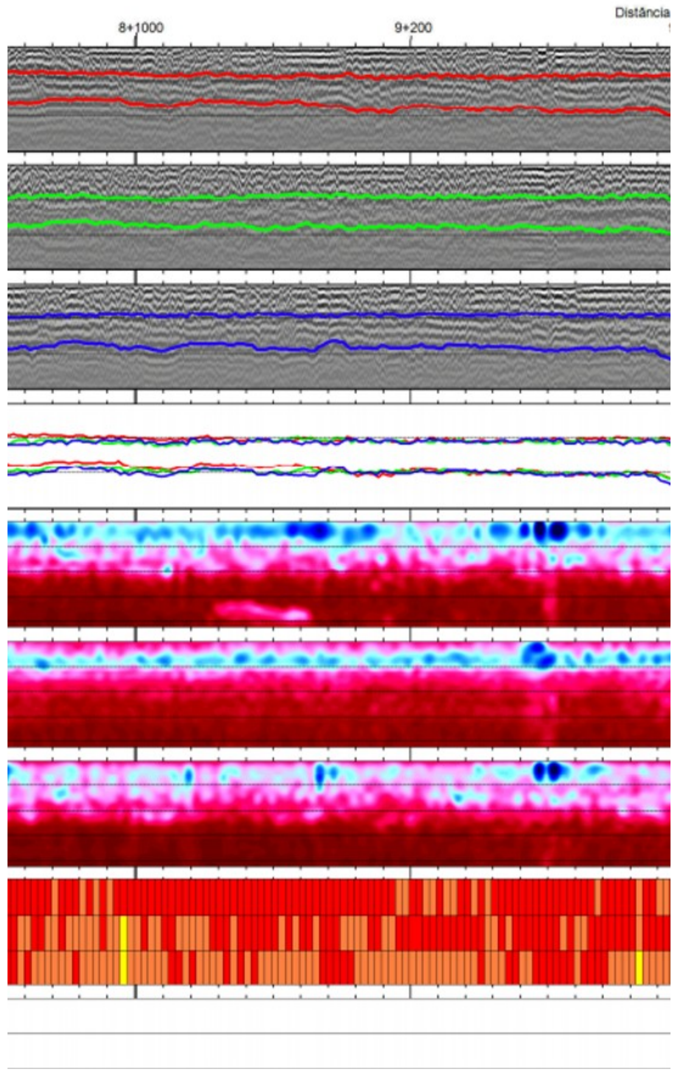
MRAIL

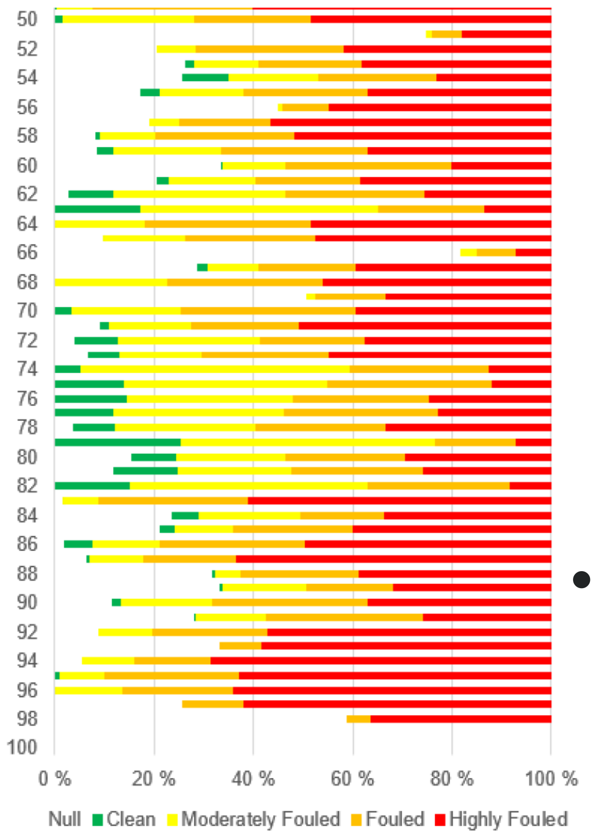




- The MRS average modulus: **33 MPa**
- Low track modulus areas 200 km
- Hight influence of the wet season

GPR





- 60% of the lines exceed the recommended contamination limit (40% fines).

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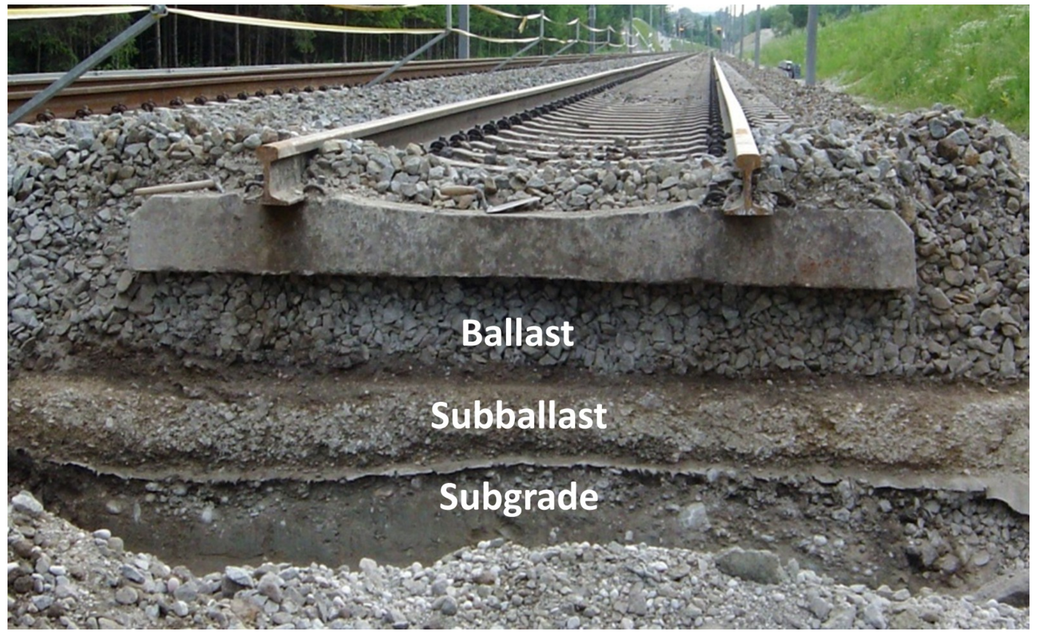
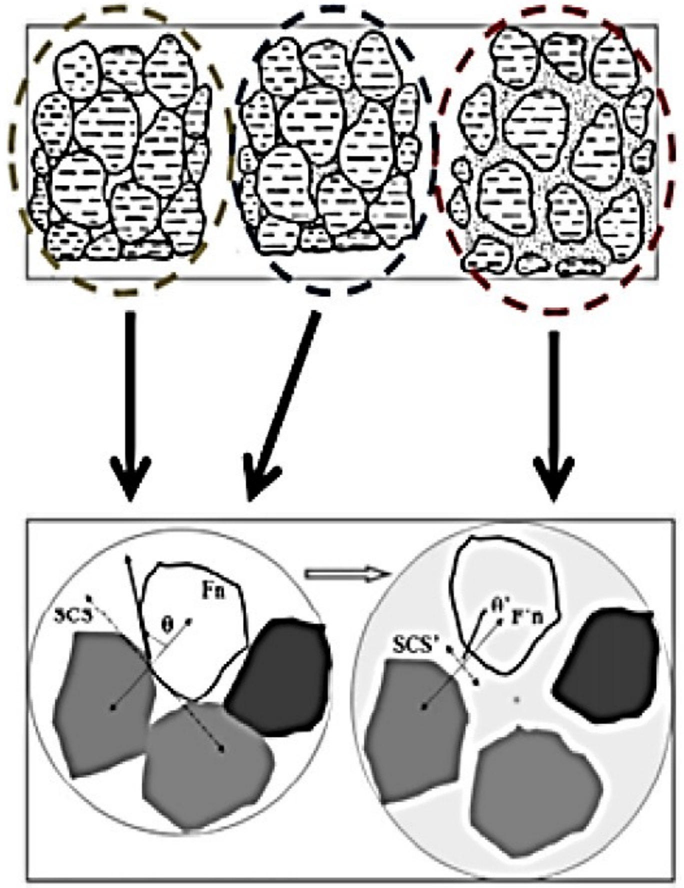
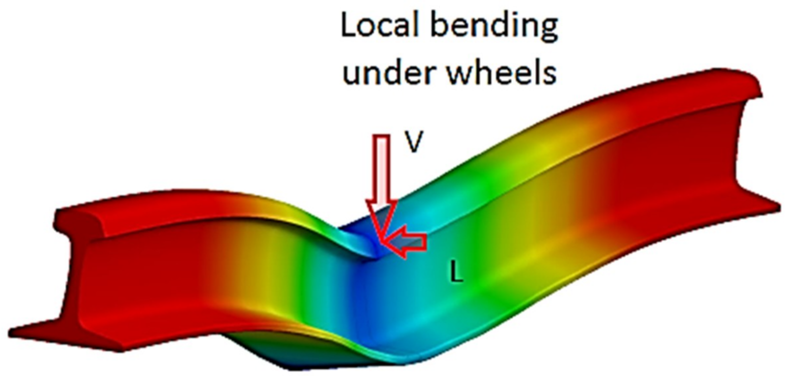
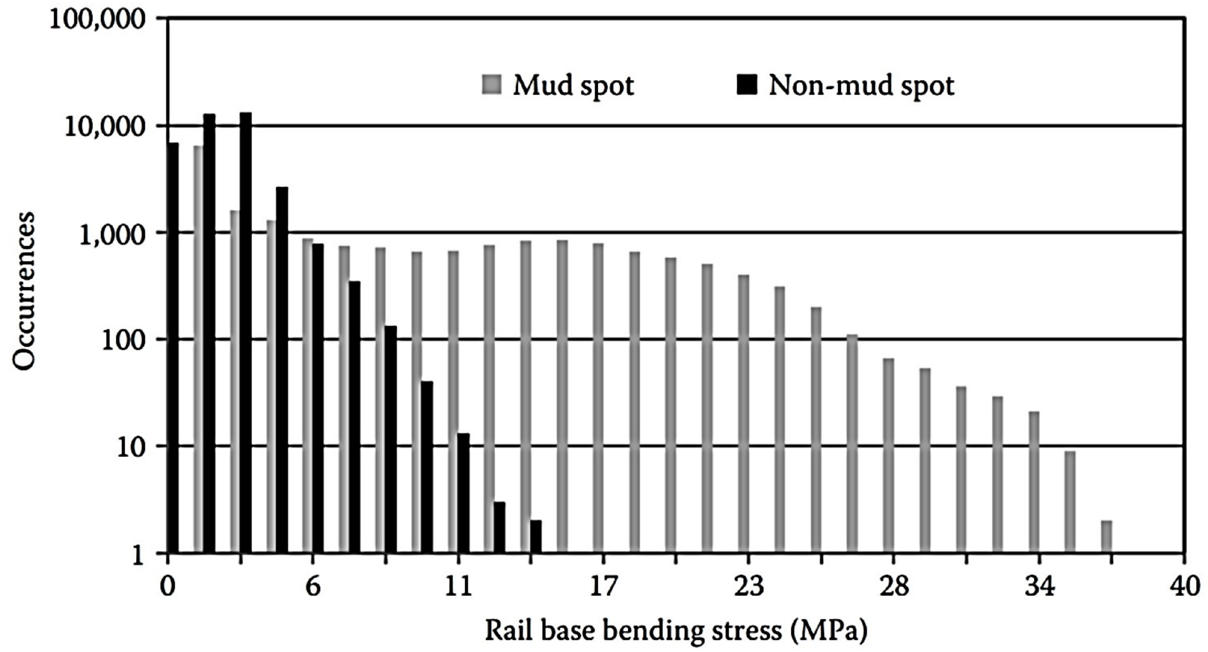
Track mechanical behavior







Example of Rail bending stresses



Rail bending stresses influenced by mud spot (Li et. al., 2015)

Broken rail due fatigue - MRS track

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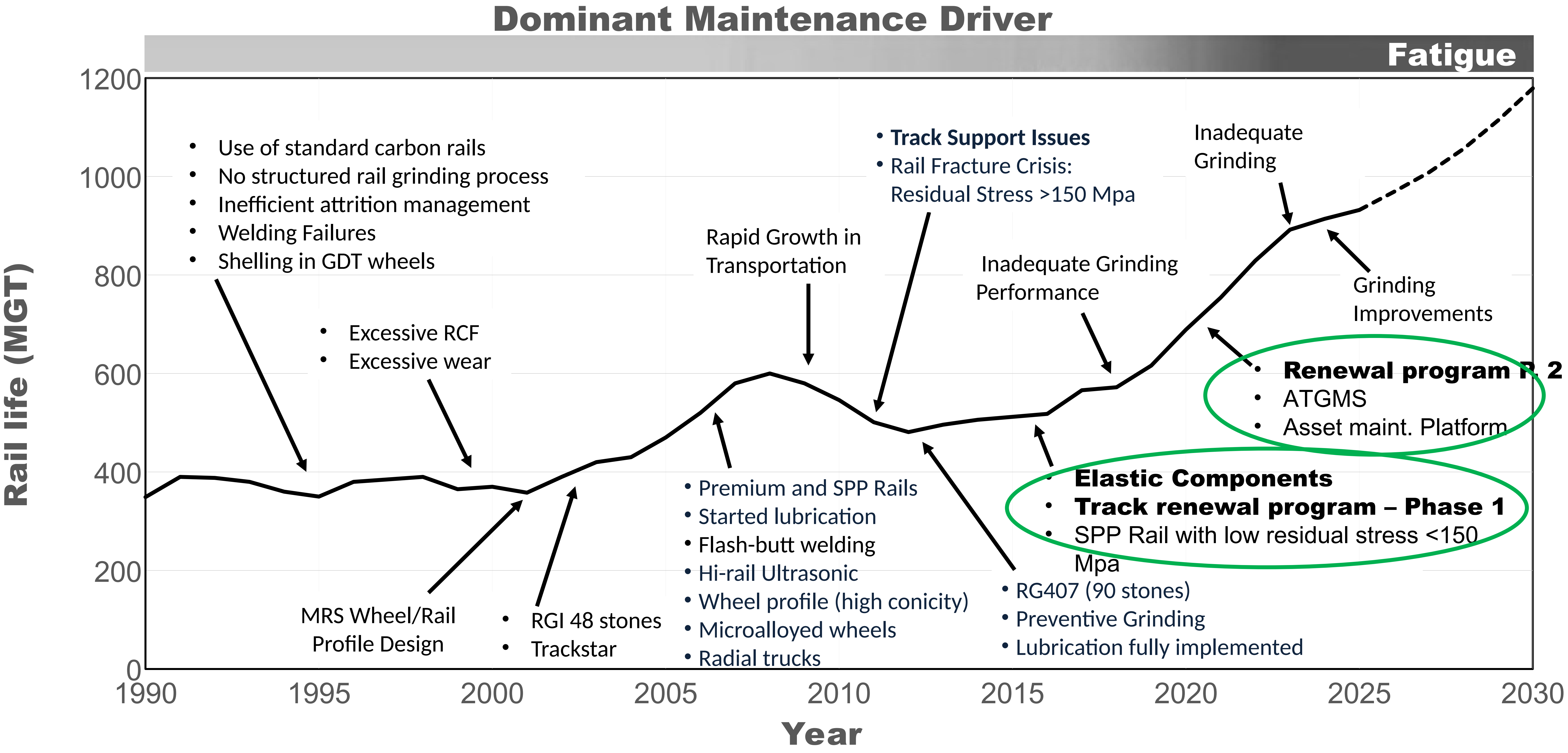
Rail Life (1996–Present): Key Events



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Strategic Track Plan

2015	2016	2017	2018	2019	2020	2021	2022

Reduce rail base fractures

- Use of Elastic Components on wood crossties
- SPP Rail with low residual stress <150 Mpa

Improvements in Concrete Tie Resilience

- Rail seat
- Contact with the ballast

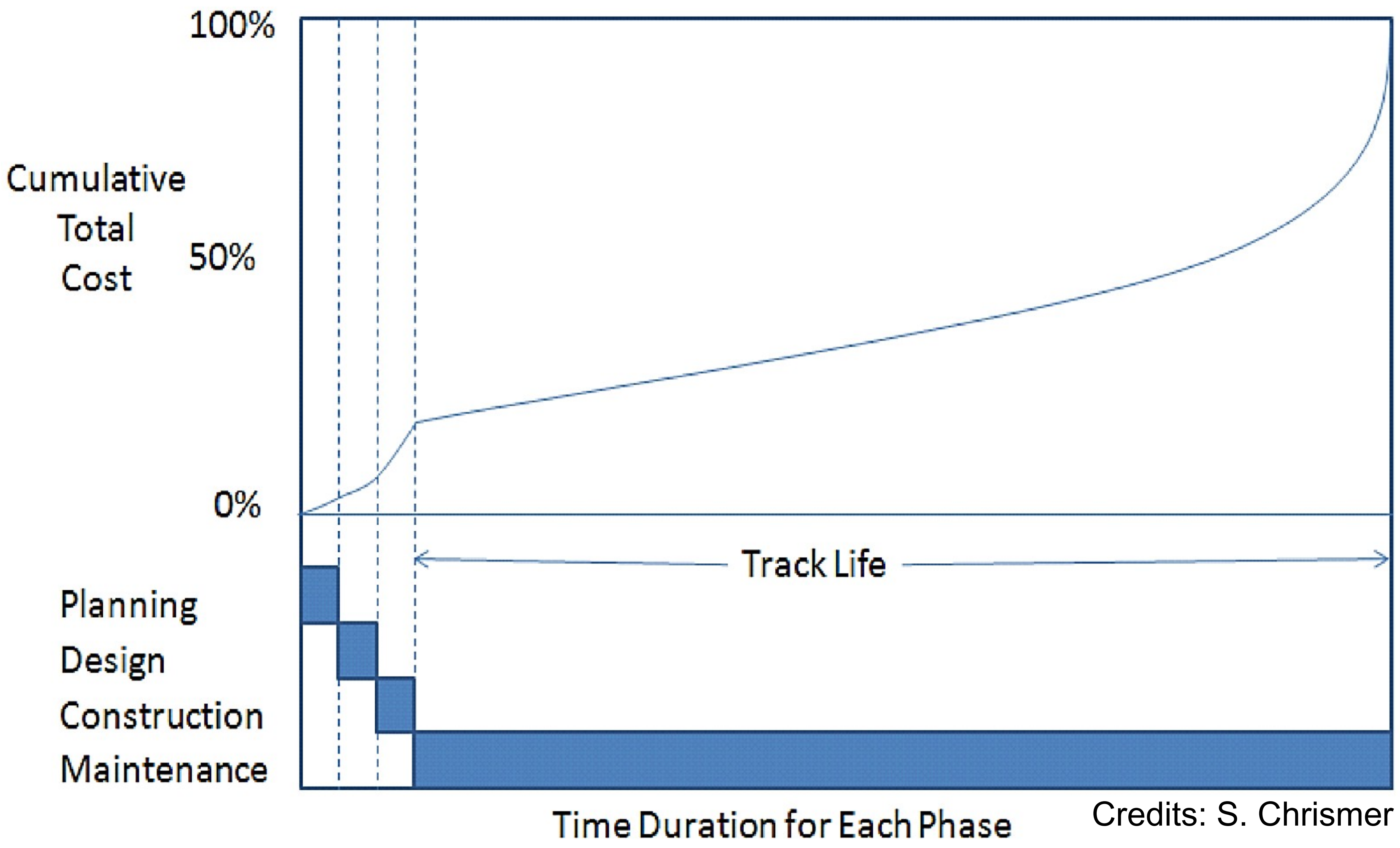
Start the track renewal program

- Drainage restoration
- Undercutting
- Tie replacement phase 1 – steel and wood
- Tie repl. Phase 2 Concrete

Implement Predictive Maintenance

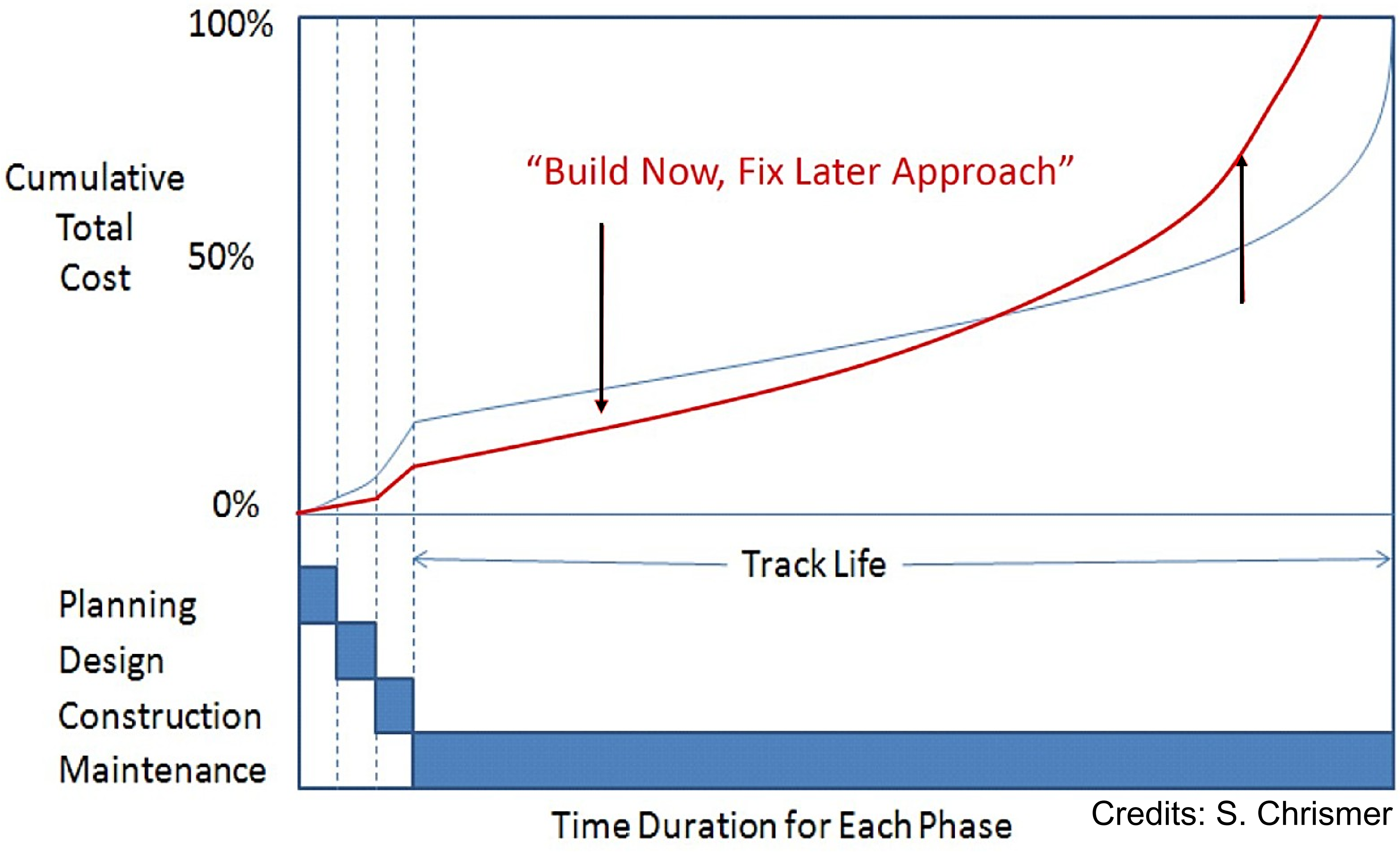
- Integrate track data into an asset management platform
- Acquire autonomous equipment's

LIFE-CYCLE COST CONSIDERATIONS



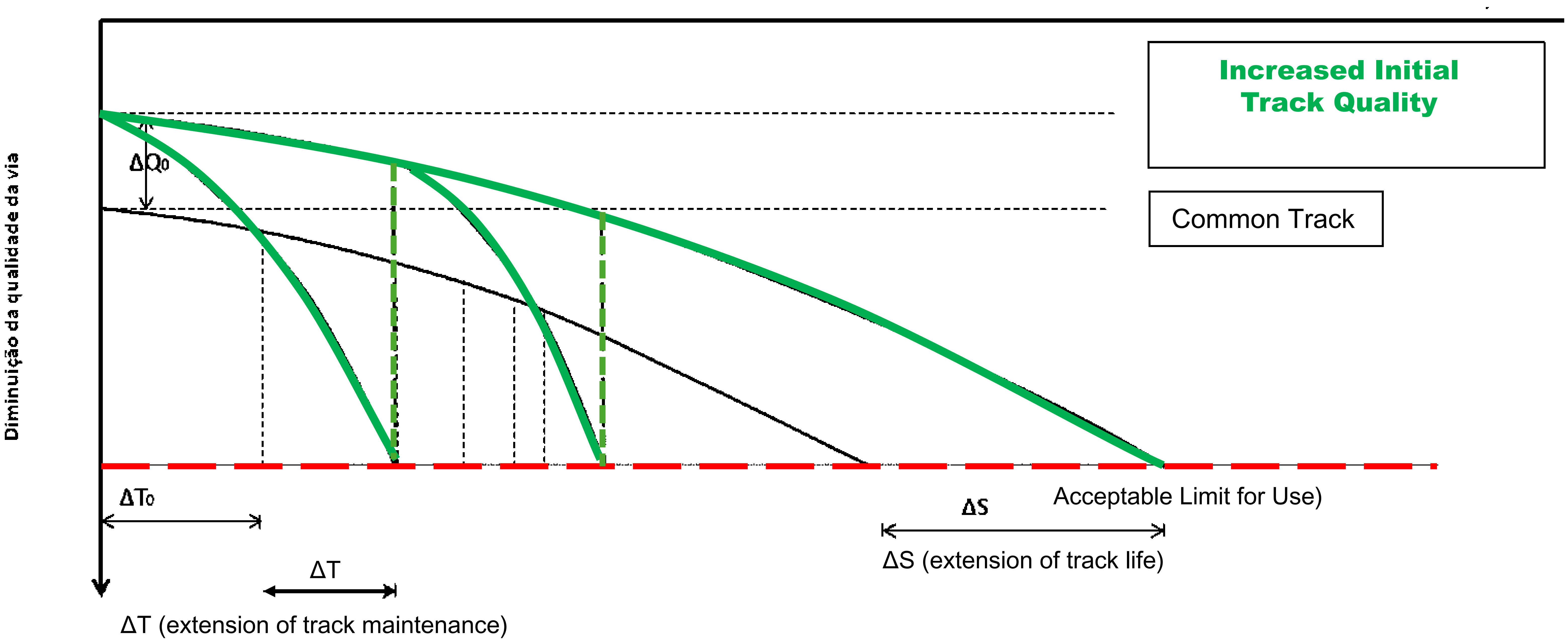
Credits: S. Chrismer

LIFE-CYCLE COST CONSIDERATIONS



Credits: S. Chrismer

Extending Service Life Without Compromising Quality



Track instrumentation

Track Behavior Evaluation under MRS Conditions:

- Analysis of ties, fasteners, Rail pads and under-tie pads
- 400m fully instrumented section (1,700 MGT to date)

Key Insights:

- Supported track renewal design
- Improved performance with pads
- Tamping cycle effectiveness
- Fastener durability assessment

test track construction

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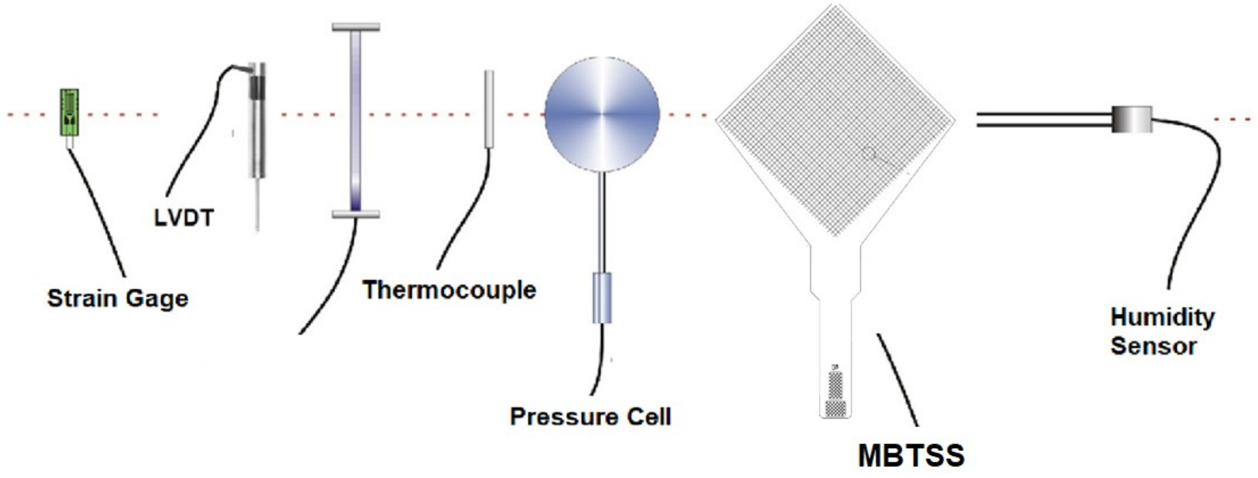
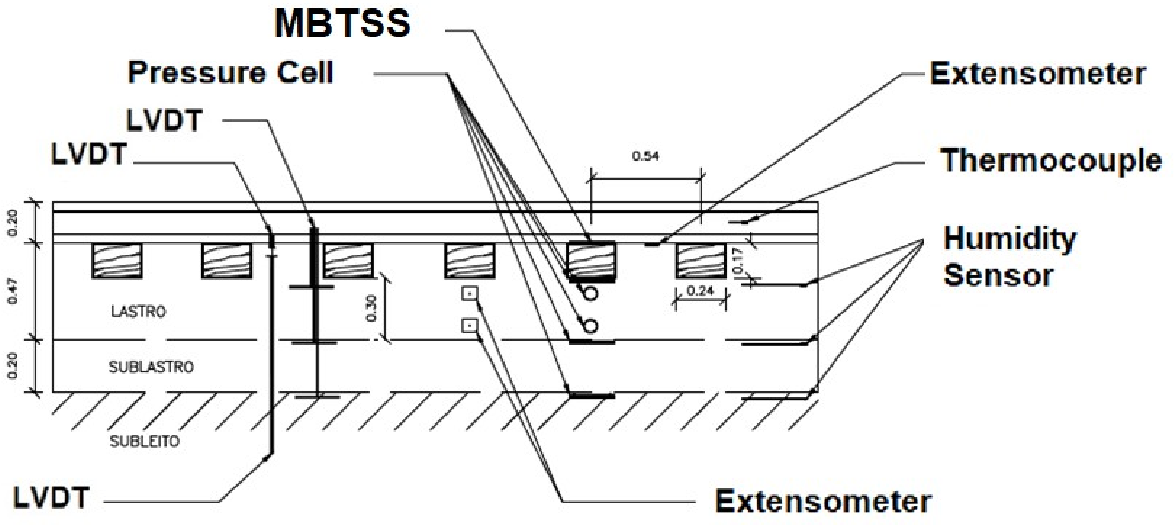
Track instrumentation

Instrumentation Overview

- Total pressure cells, MBTSS sensors
- strain gauges
- LVDTs (Linear Variable Differential Transformers)
- Temperature
- humidity

Sensors were installed across various crossties types, track layers, depths, and loading conditions.





track instrumentation

Broken rail due base fatigue in MRS track

45% of mainline rail breaks

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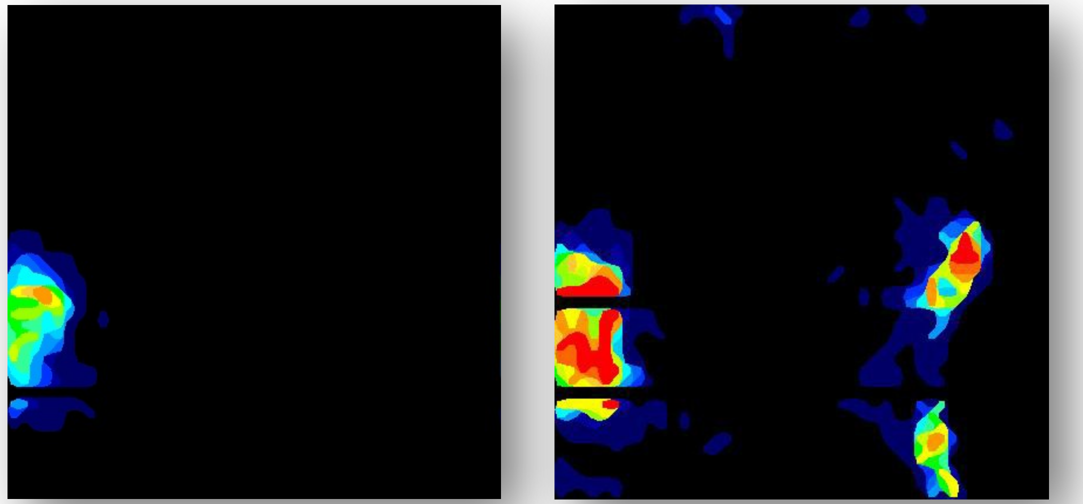
Use of Rail Pads on Wood Ties

$$\downarrow P = \frac{F}{A} \uparrow$$

Not equipped



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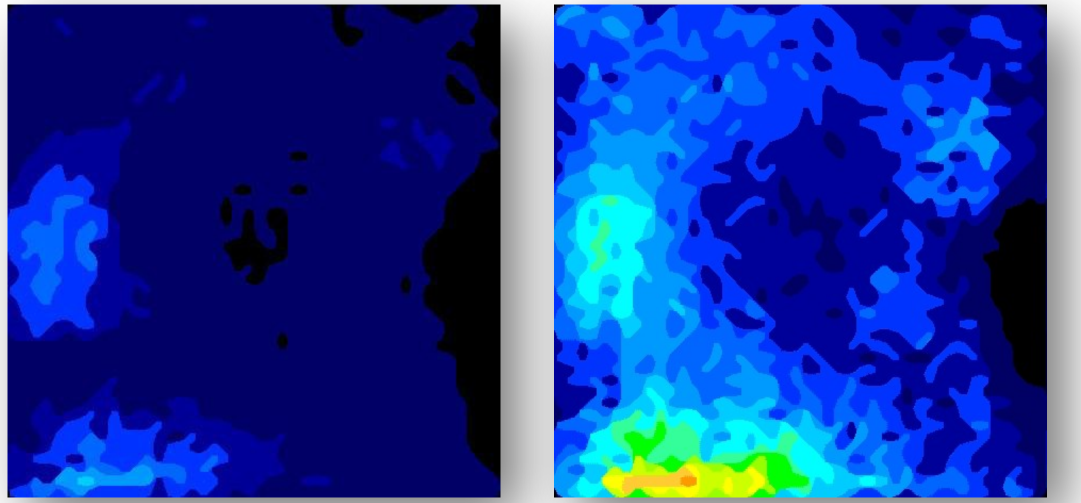
– **Contact area: < 20%**

With Railpad



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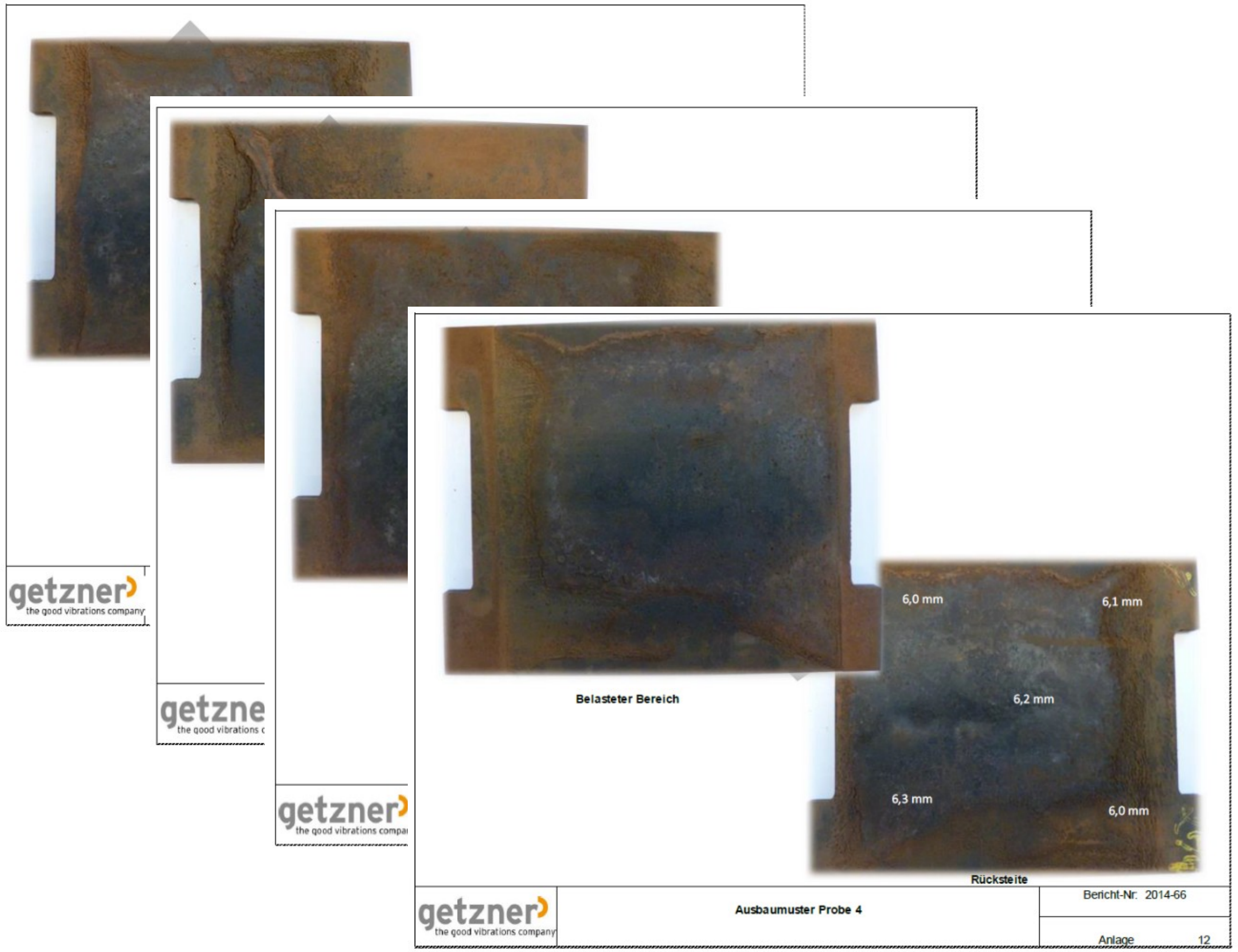
– **Contact area: > 90%**

9 years in service test – Approx. ≈ 1.500 MGT



Maintaining Resilience and Elasticity

99% reduction in rail base breaks at equipped locations

primarily tunnels and bridges

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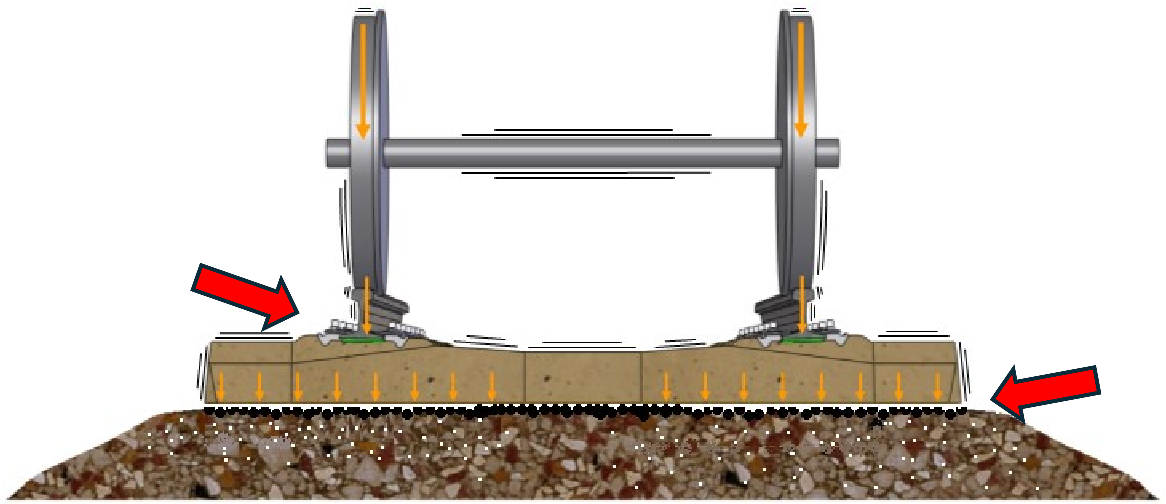
Challenges of replacing wood by concrete

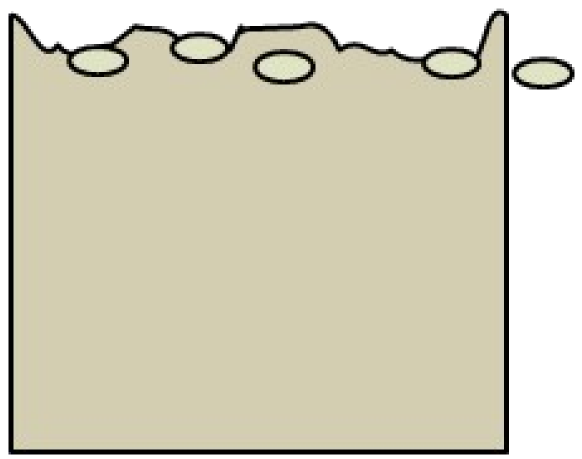
- The introduction of concrete ties (1950s) significantly increased track stiffness
- Requiring a reevaluation of the track structure and its components

- **Production quality control**
- **High durability & weight**



- **Bad contact area**
- **Low elasticity**

Rail seat deterioration



Zeman et al 2011

Poor contact tie/ballast

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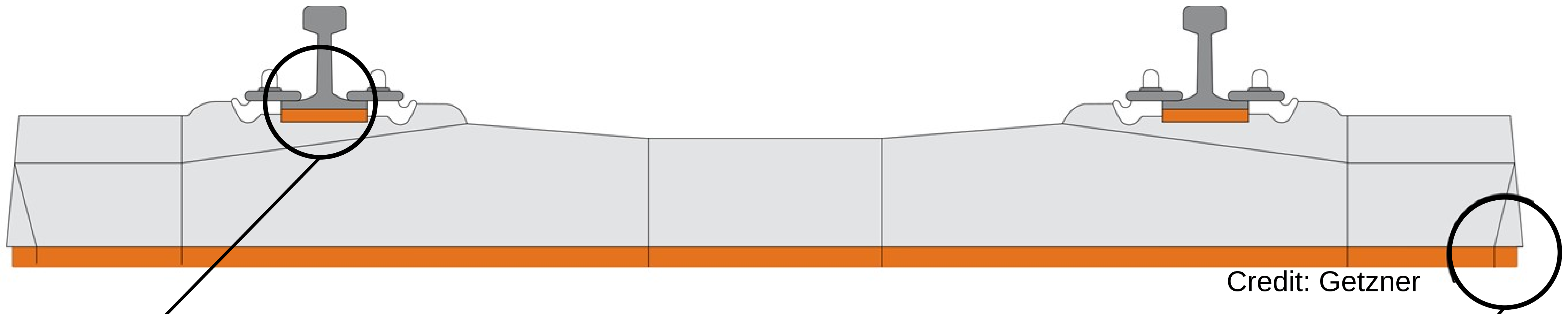
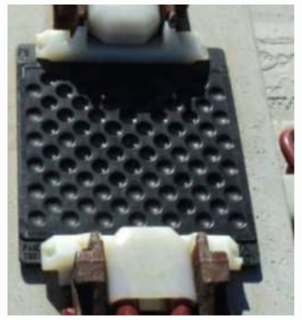
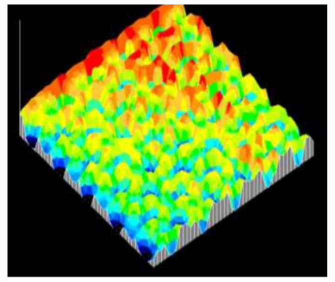
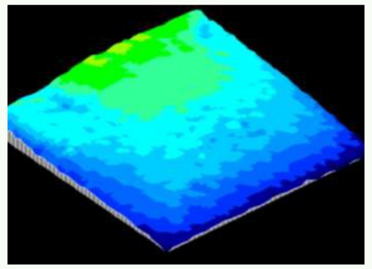
Improve to take full advantage of concrete tie potential



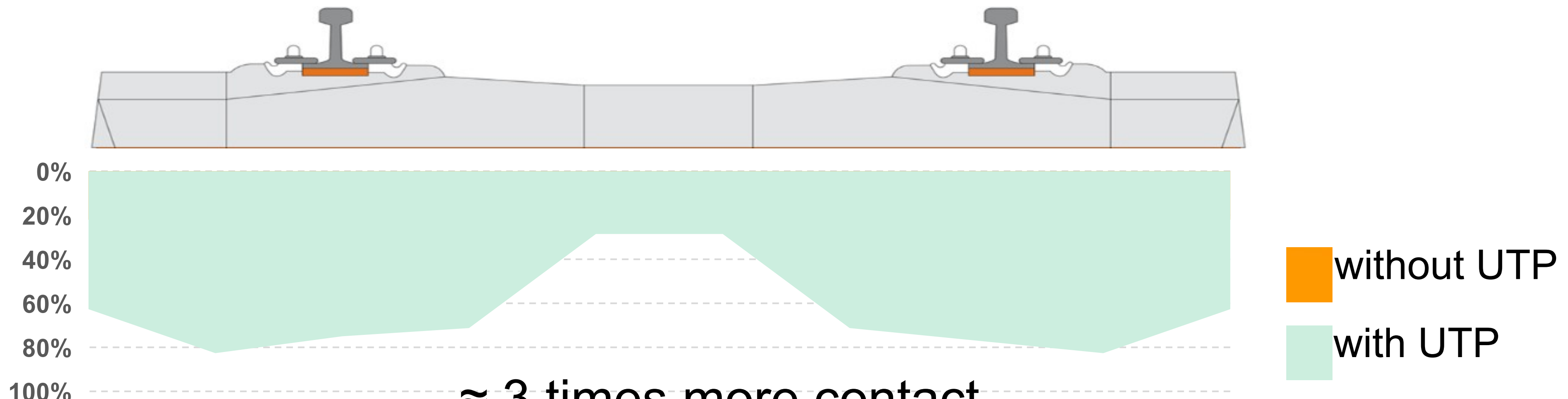
Credit: Getzner

Rail pad results

- Resilient pads increase the area of contact between the rail and concrete by 96%
- Preserves the concrete from the Rail Seat abrasion

contact area %	
Common polyurethane 40 to 65 %	Cellular polyurethane 88 to 96 %
 	 

Under tie pad results



≈ 3 times more contact

- Average contact area with pad: 60%
- Tamping cycle reduction from 2 to 3 times
- Average pressure reduction under tie from 1,1 to 0,5 MPa

Rail seat deterioration

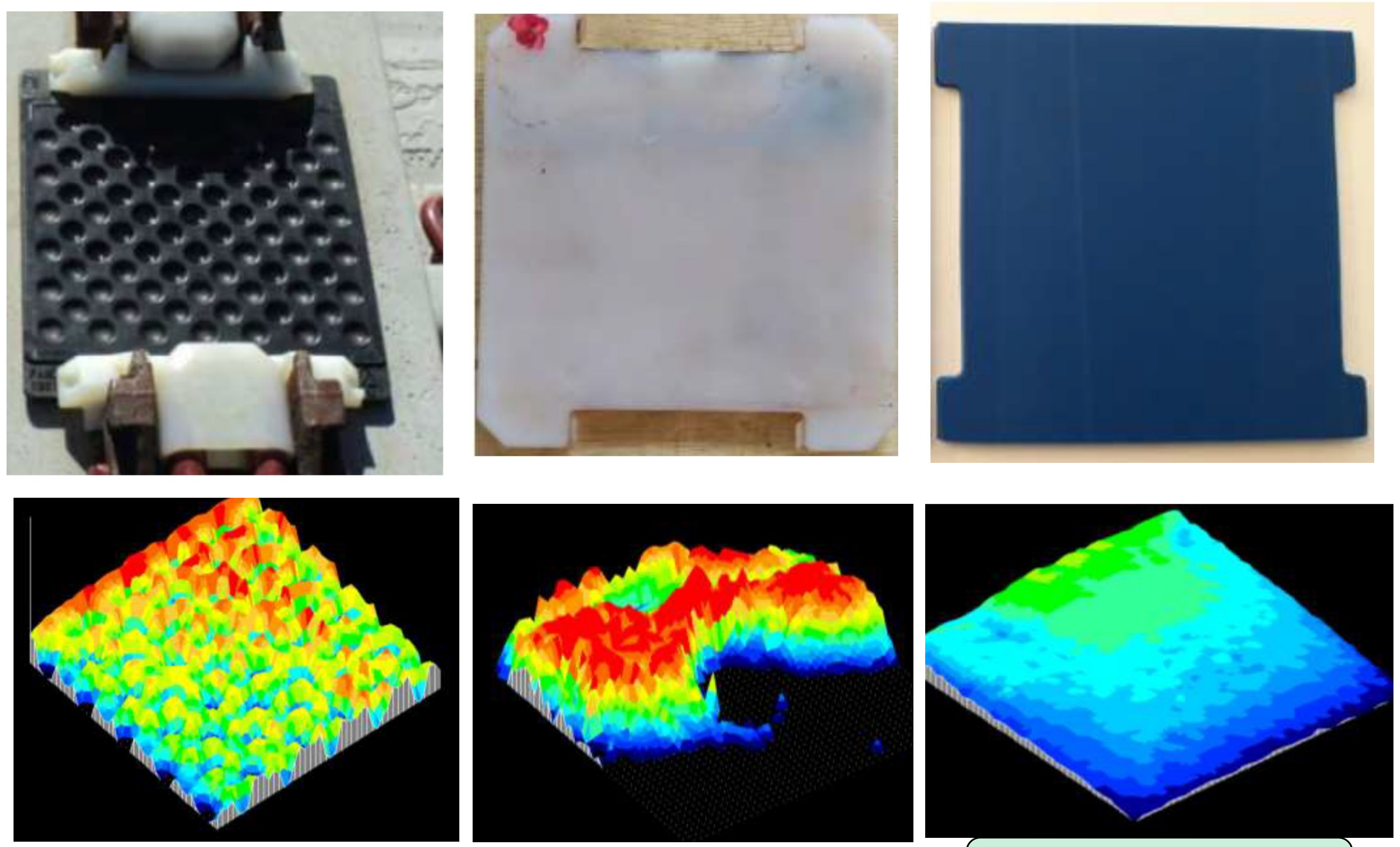
Rail seat deterioration

Choros-et-al.-2007

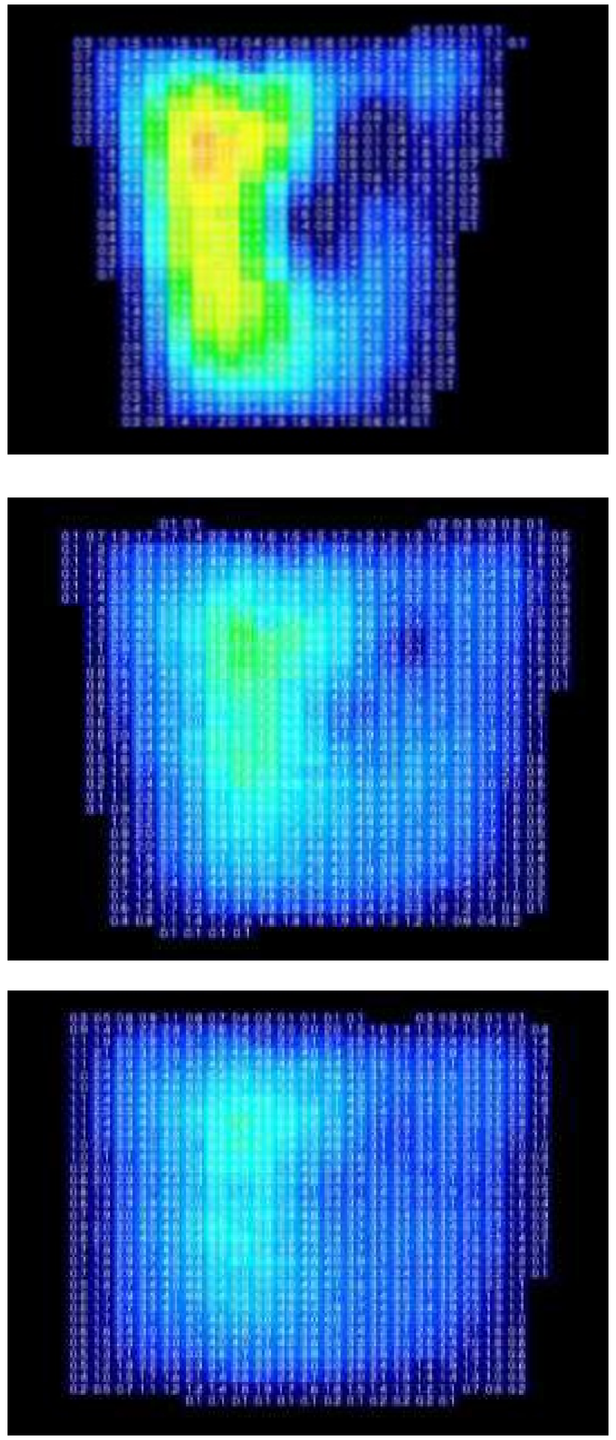
RSA – 310 MGT – 2 years in service (2015-2016)

Rail pad tests

Rail pad pressure results



Model A   Model B   Model C



Model C: version 1

Model C: version 2

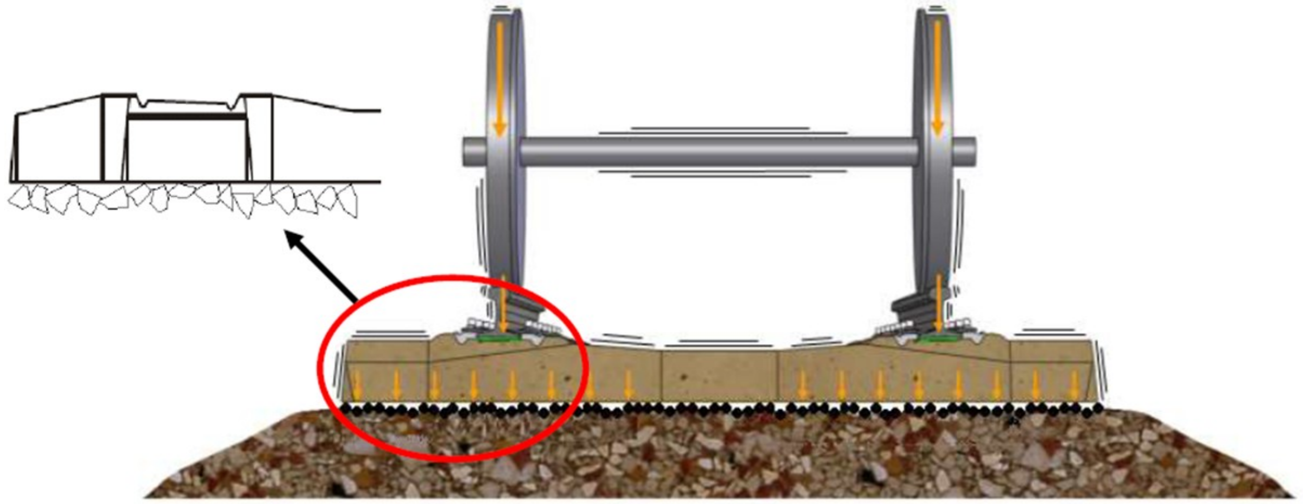
Model C: version 3

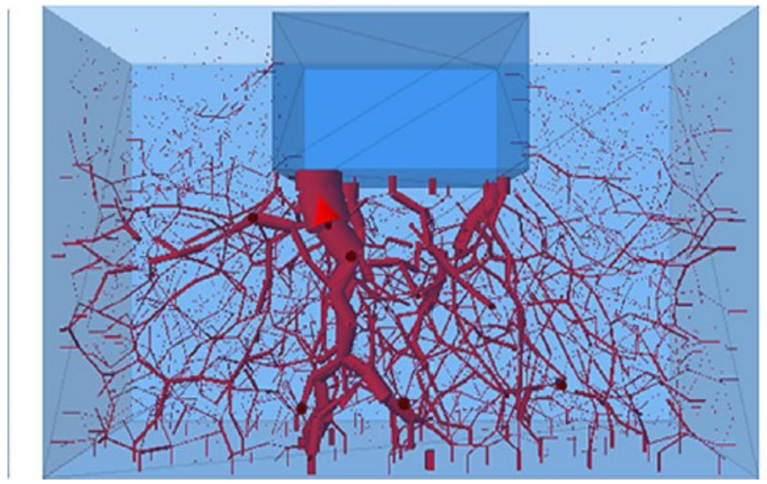
ELASTICITY

Tie-Ballast contact

Few aggregates support the tie, depending on:

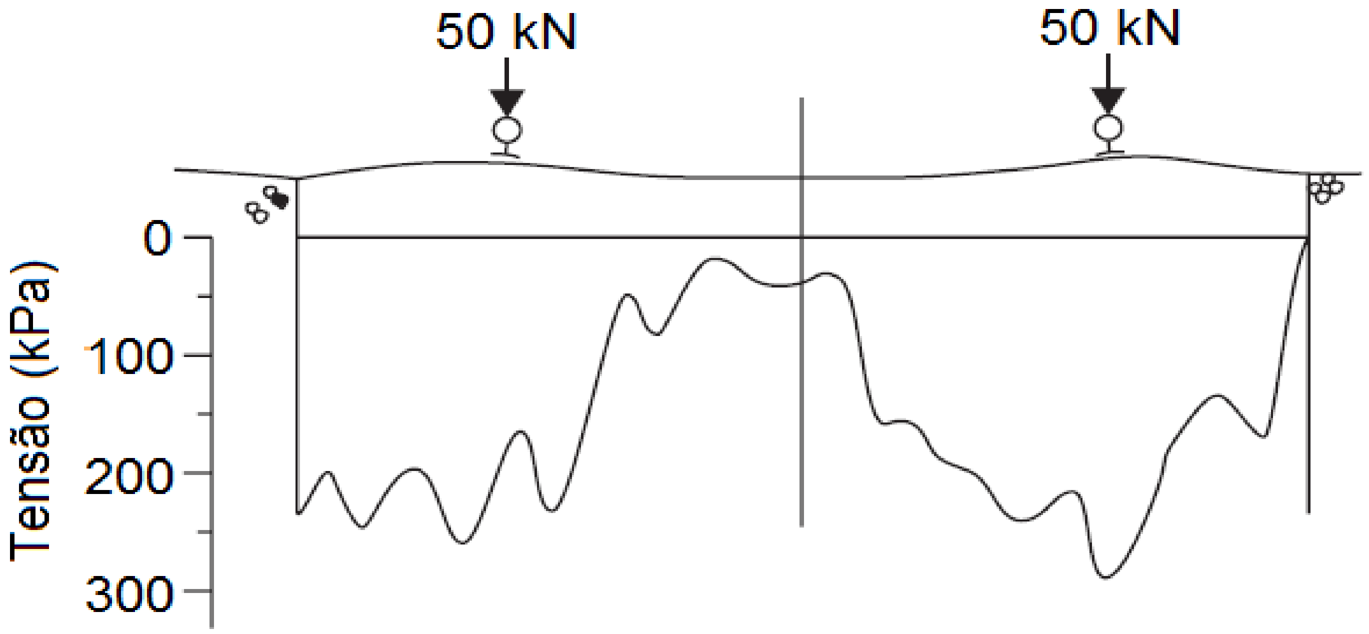
- Ballast grading;
- Ballast shape;
- Tie dimension;
- Load.



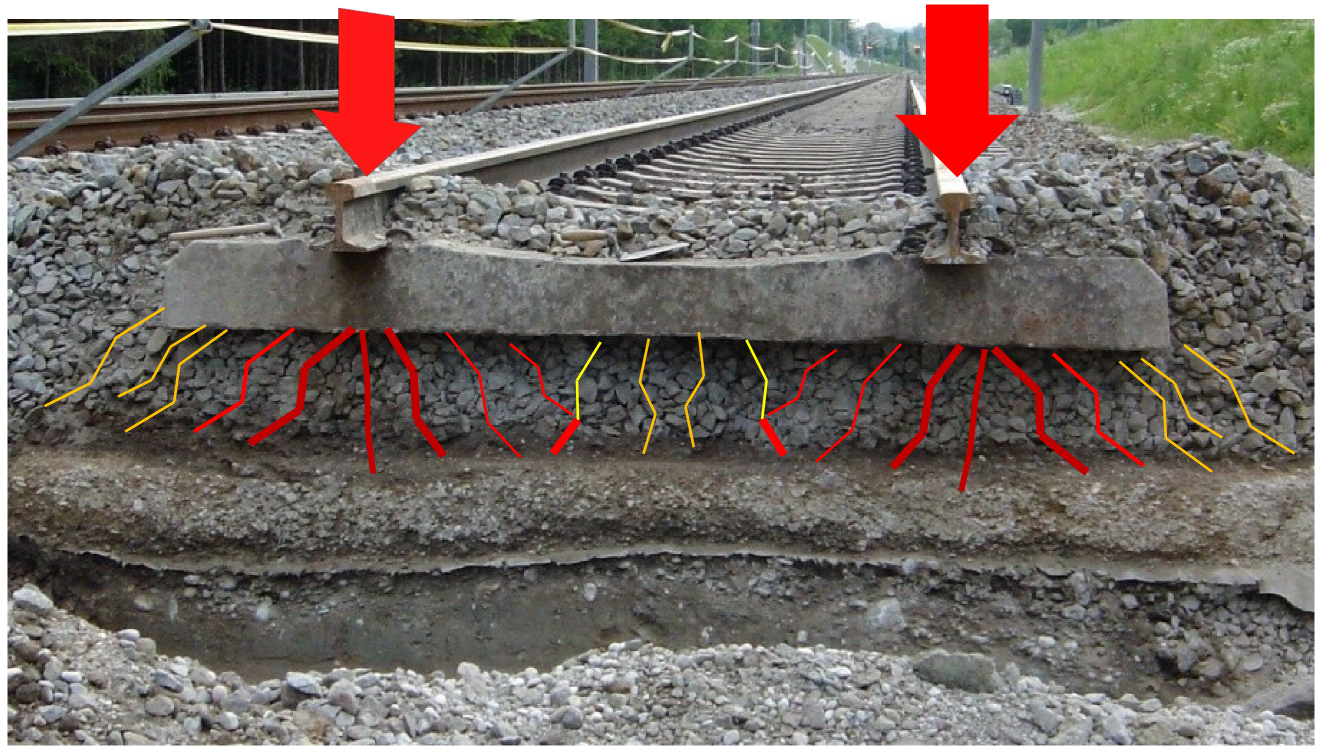


Huiqi Li et al 2017

Stress distribution



Shenton, 1975



Strategies to improve tie–ballast interaction

Increase tie size

- Increases the weight of the concrete tie
- Maintenance becomes more challenging

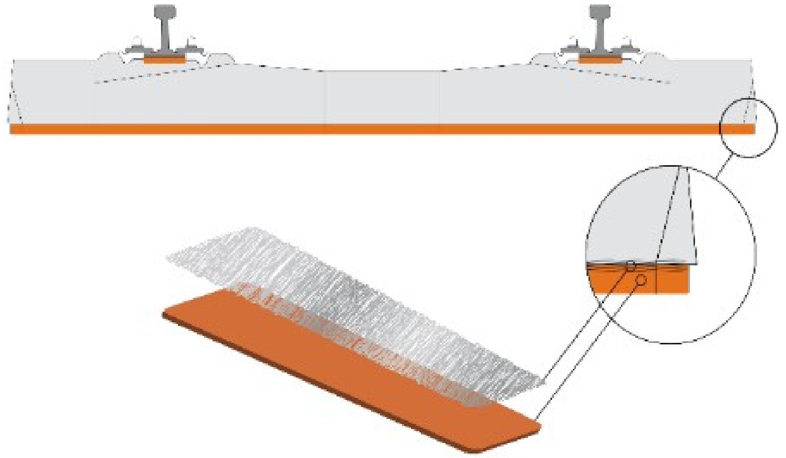
Adoption of smaller ballast gradations

- Reduces ballast drainage capacity
- Compromises final strength and interlock

More frequent maintenance (tamping)

- Reduces the ballast's service life
- More frequent ballast undercutting cycles

Under Tie Pad



- Ensures a uniform tie–ballast interface
- Improve track resilience.

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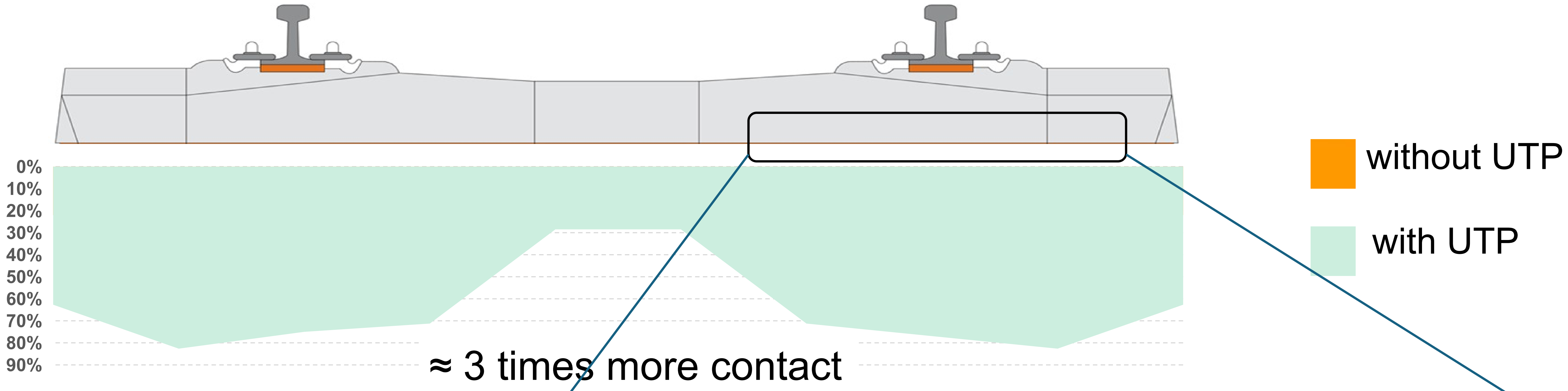
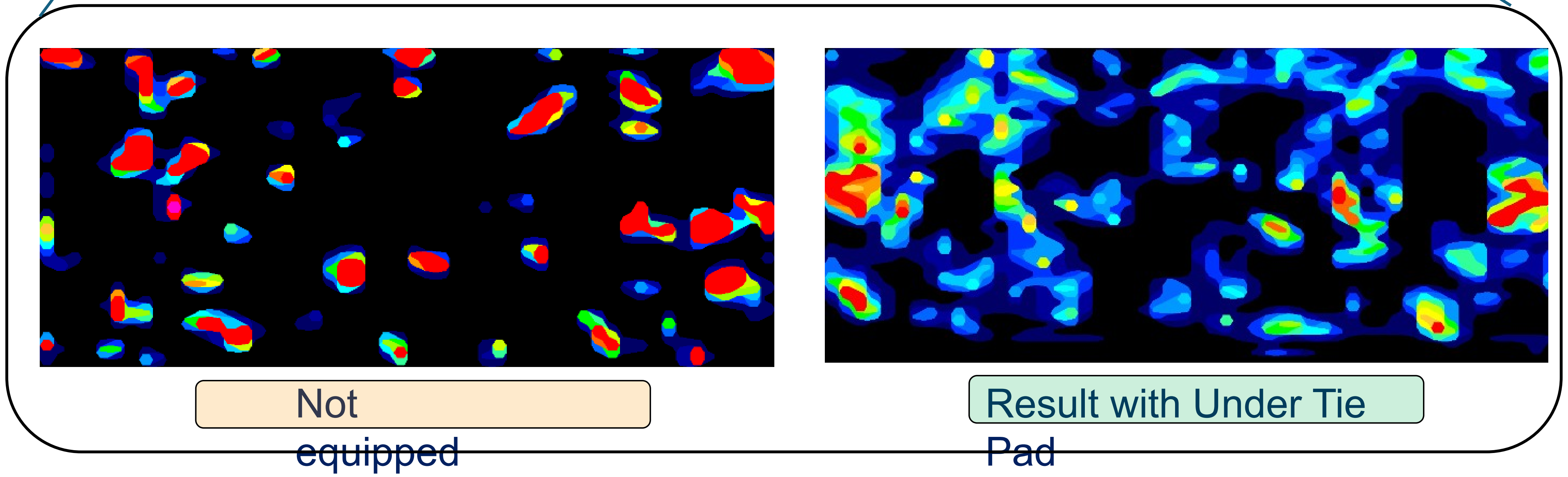
Tie-ballast contact at MRS test track



Type of tie	Entire contact (%)
Steel	17 a 28
Concrete	22 a 32
Polymer	31 a 40
Wood	46 a 55
Concrete UTP	**57 to 64**

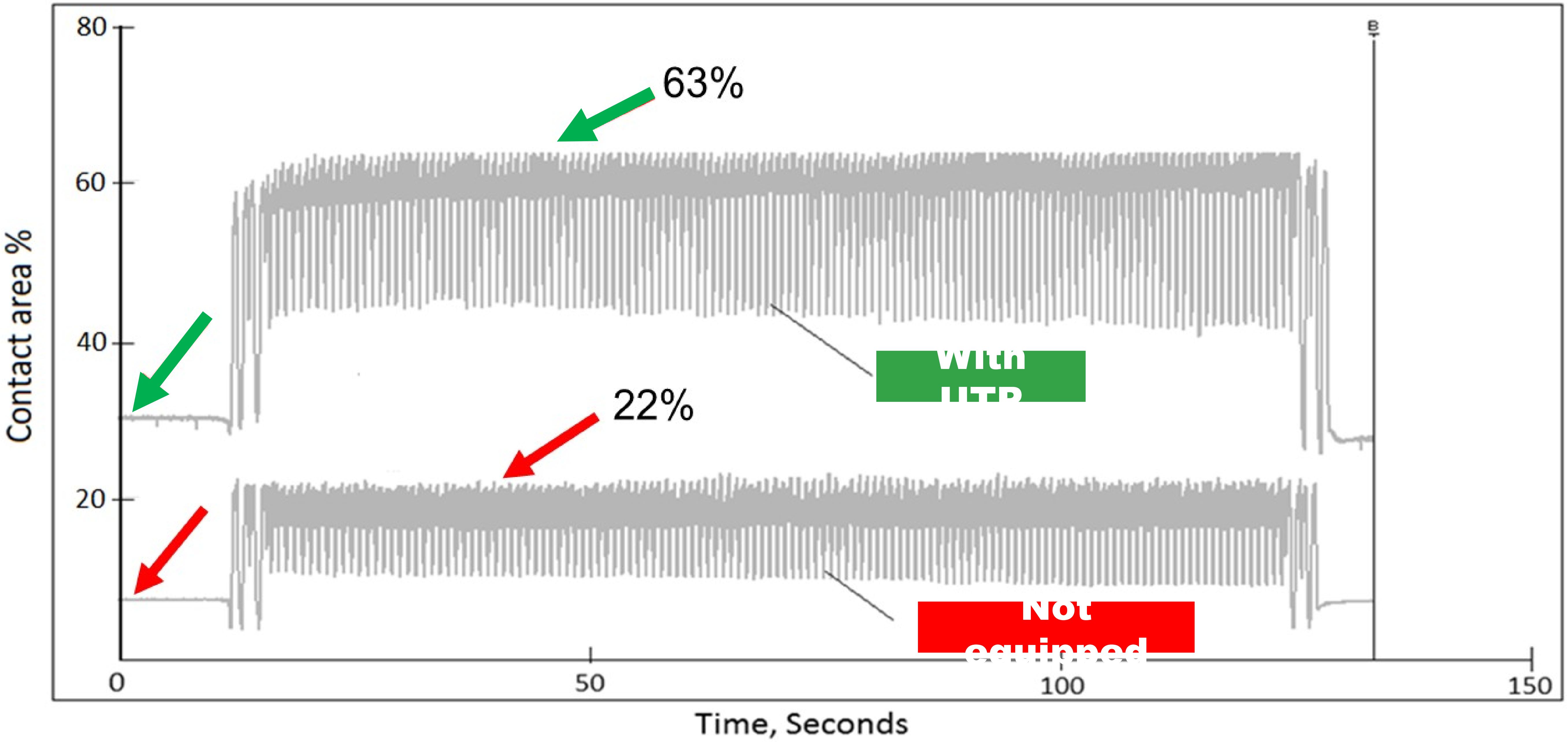


- **Average pressure reduction under tie from 1,1 to 0,5 MPa**

Results - Contact area *vs* time

Sensor set up

2 locomotives + 136 cars + 1 locomotive

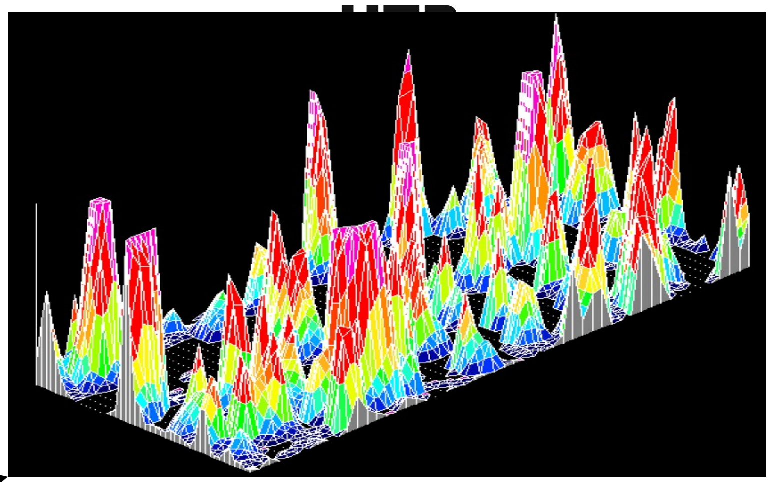


Tie-ballast contact at MRS test track

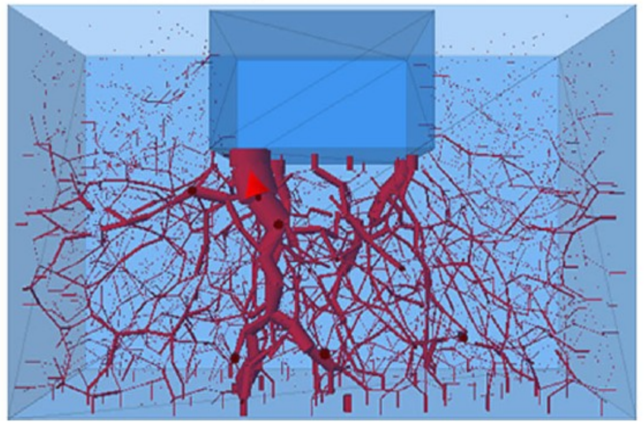
Average pressure distributions (PSI)	
Without	With UTP
150 to 230	60 to 90

Peak pressures up to 15 times higher than the uniform pressure!

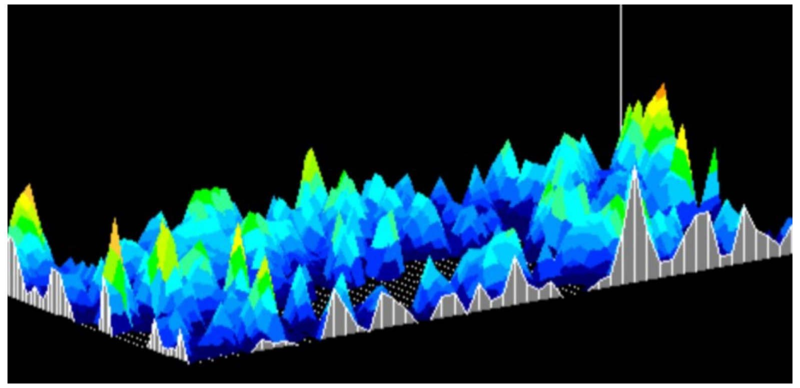
3D View without



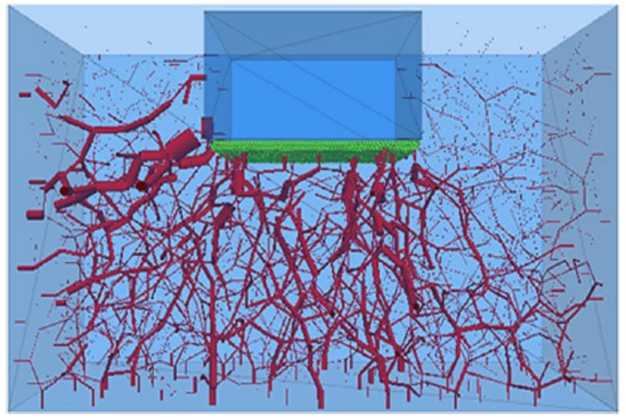
Without pad at max load



3D View with UTP



With pad at max load



Huiqi Li et al 2017

- Reduces the ballast breakdown
- Reduces the ballast settlement
- Maximum bending moment in concrete ties reduced by 20%

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Track renewal program

+100 Tournouts

+720 thousand Concrete ties with UTP

26 New machines

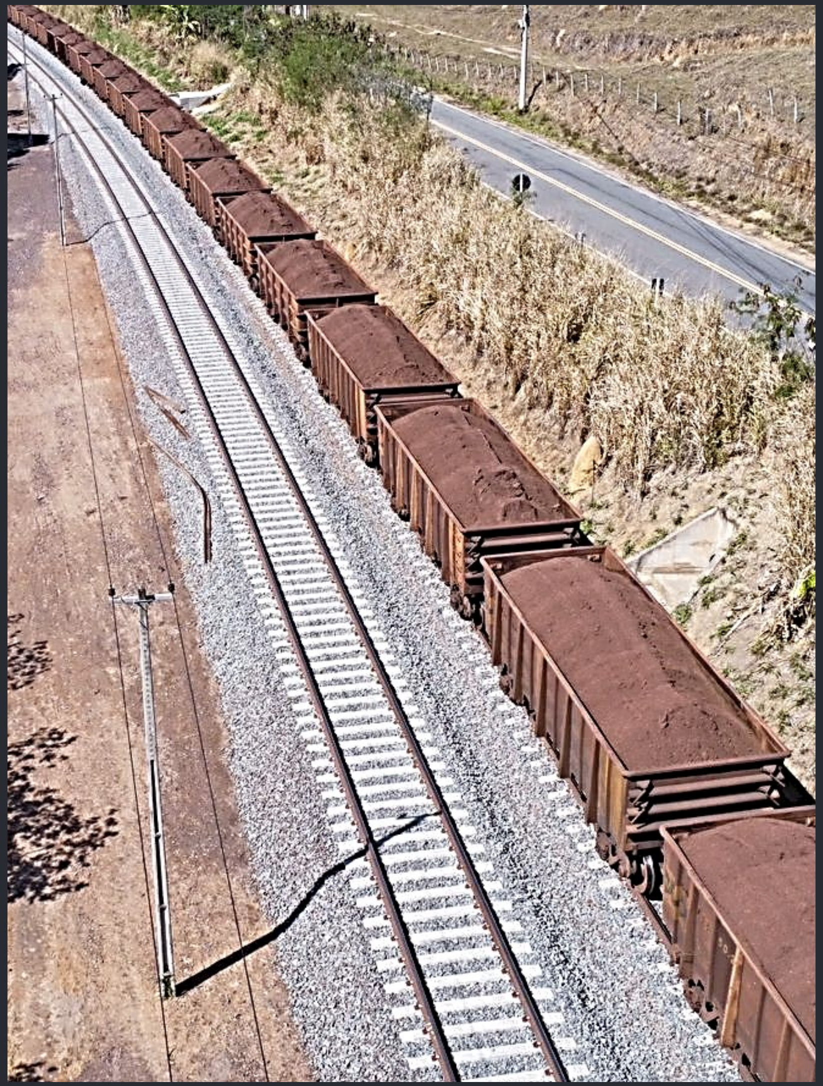
81 Service wagons

7 shops

Undercutting

Track renewal – Tie replacement

Concrete without UTP
Test section (500m)



Wood
Test section (500m)

Concrete UTP
Main line

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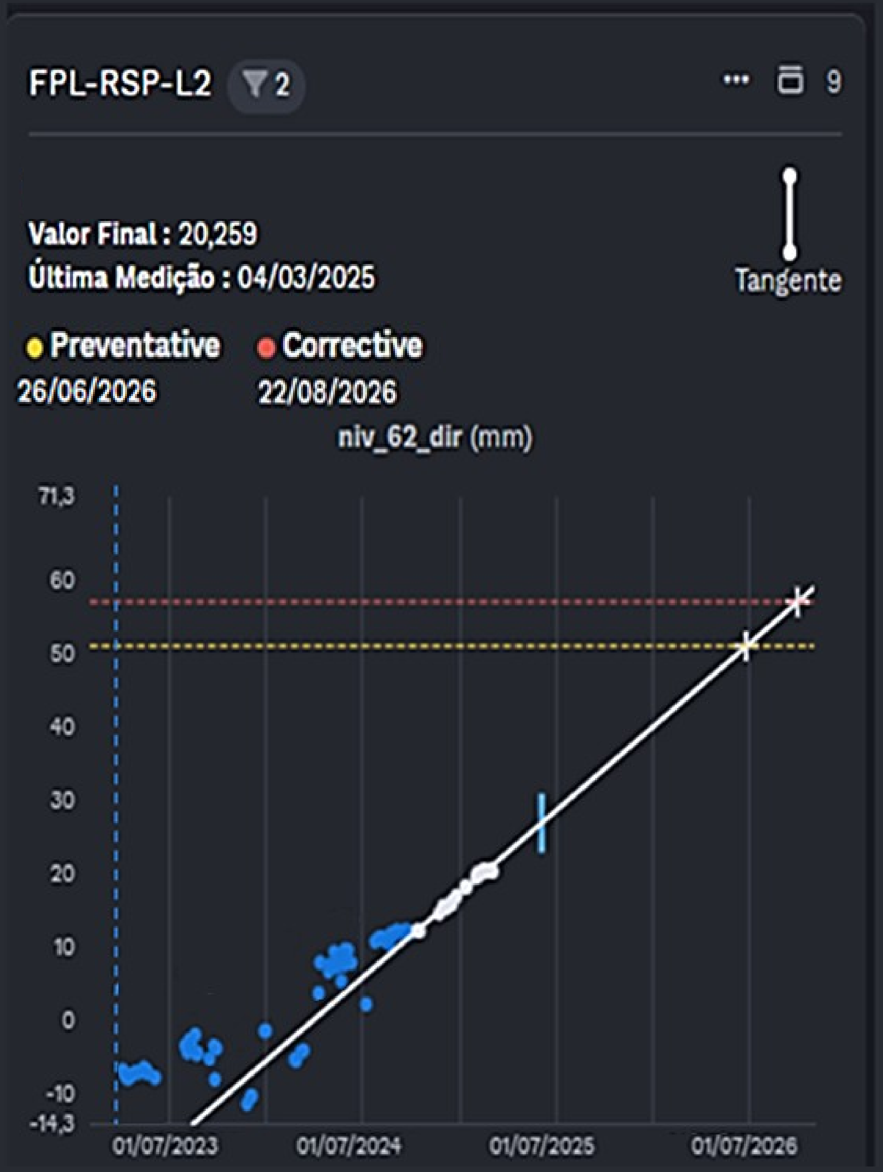
Tie replacement – geometry results

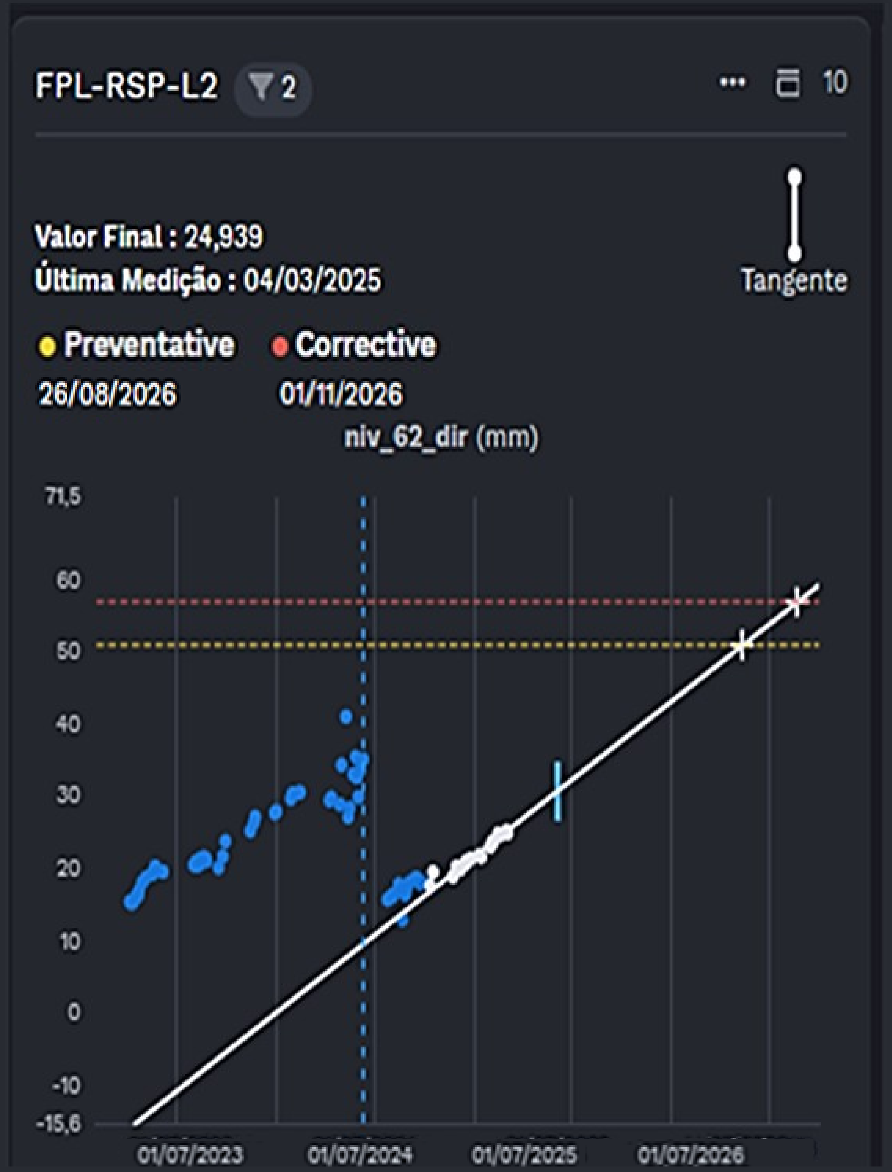
Concrete without UTP

1st tamping June 2023
Next tamping June to August 26



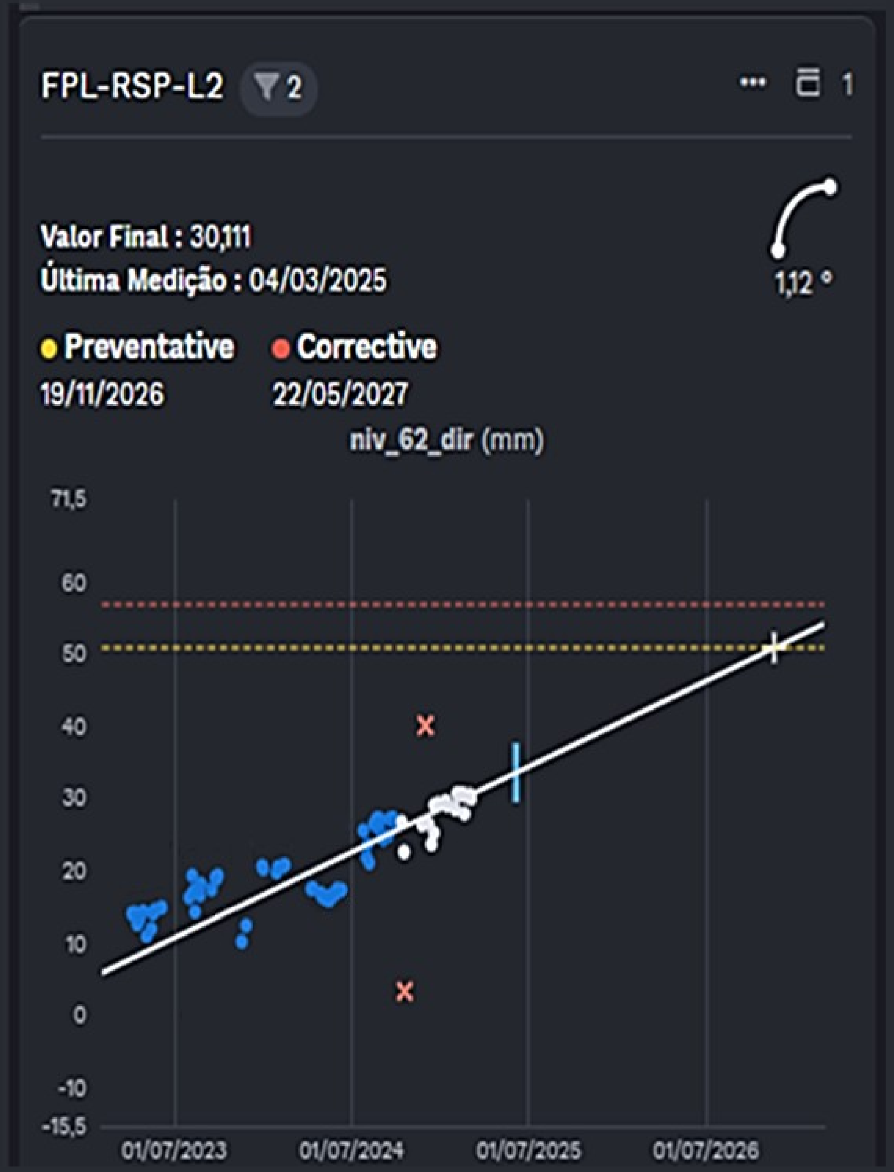
Wood

1st tamping July 2024
Next tamping Aug. to October 26



Concrete UTP

Not tamped
Next tamping Nov. 26 to May 27



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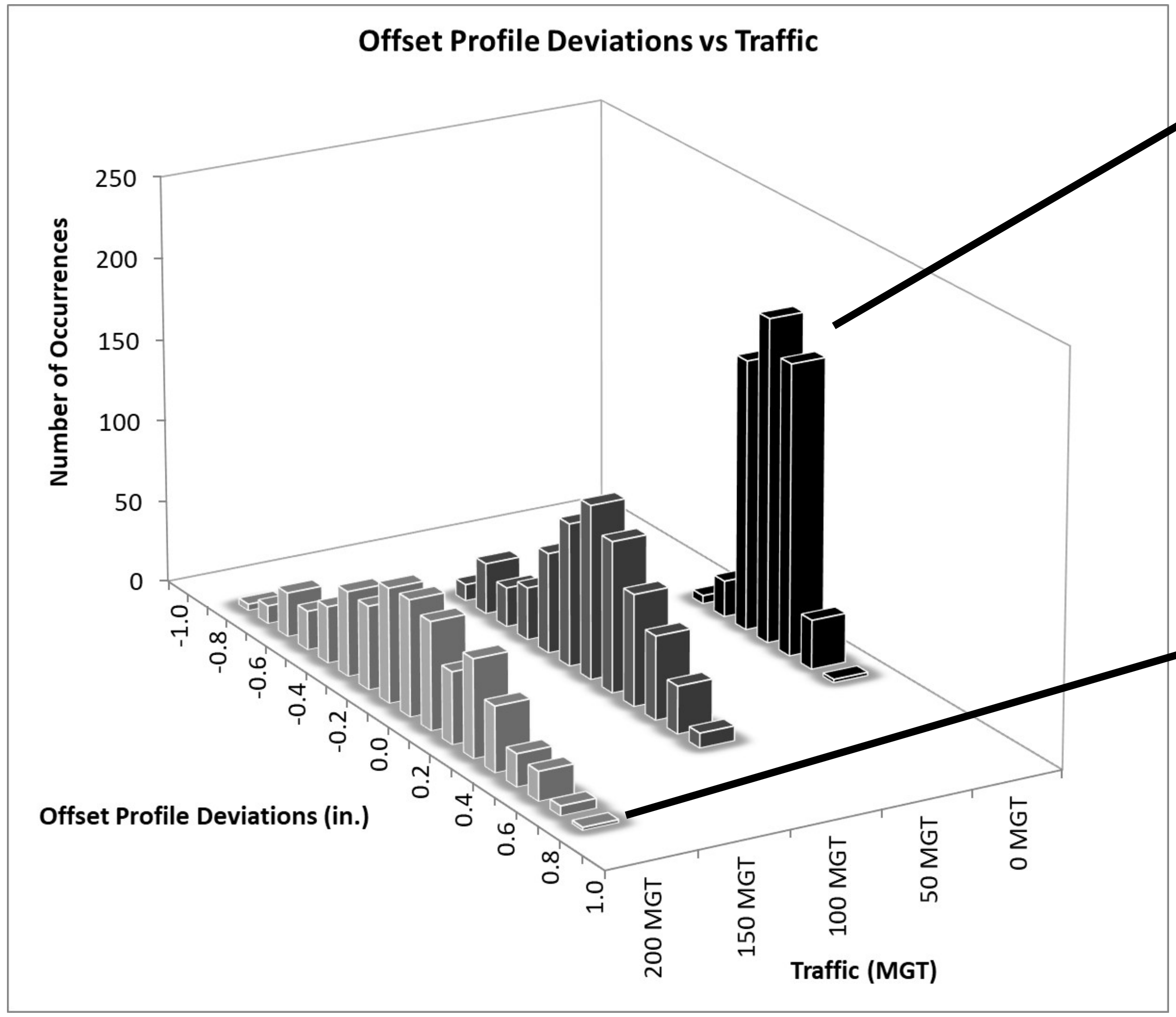
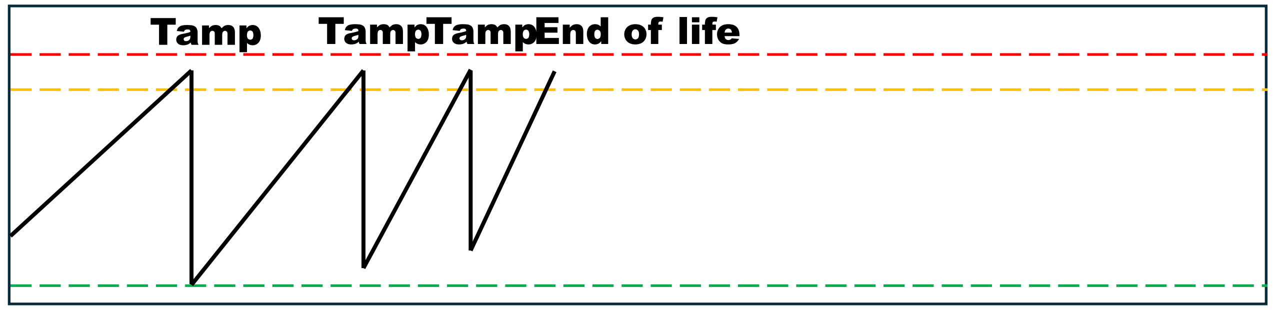
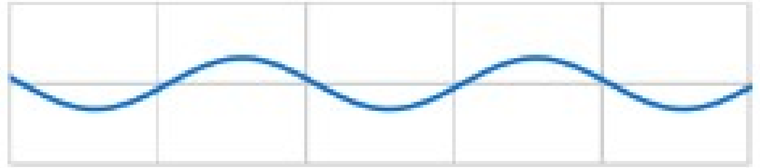
Profile measurements on concrete tracks

Concrete not equipped



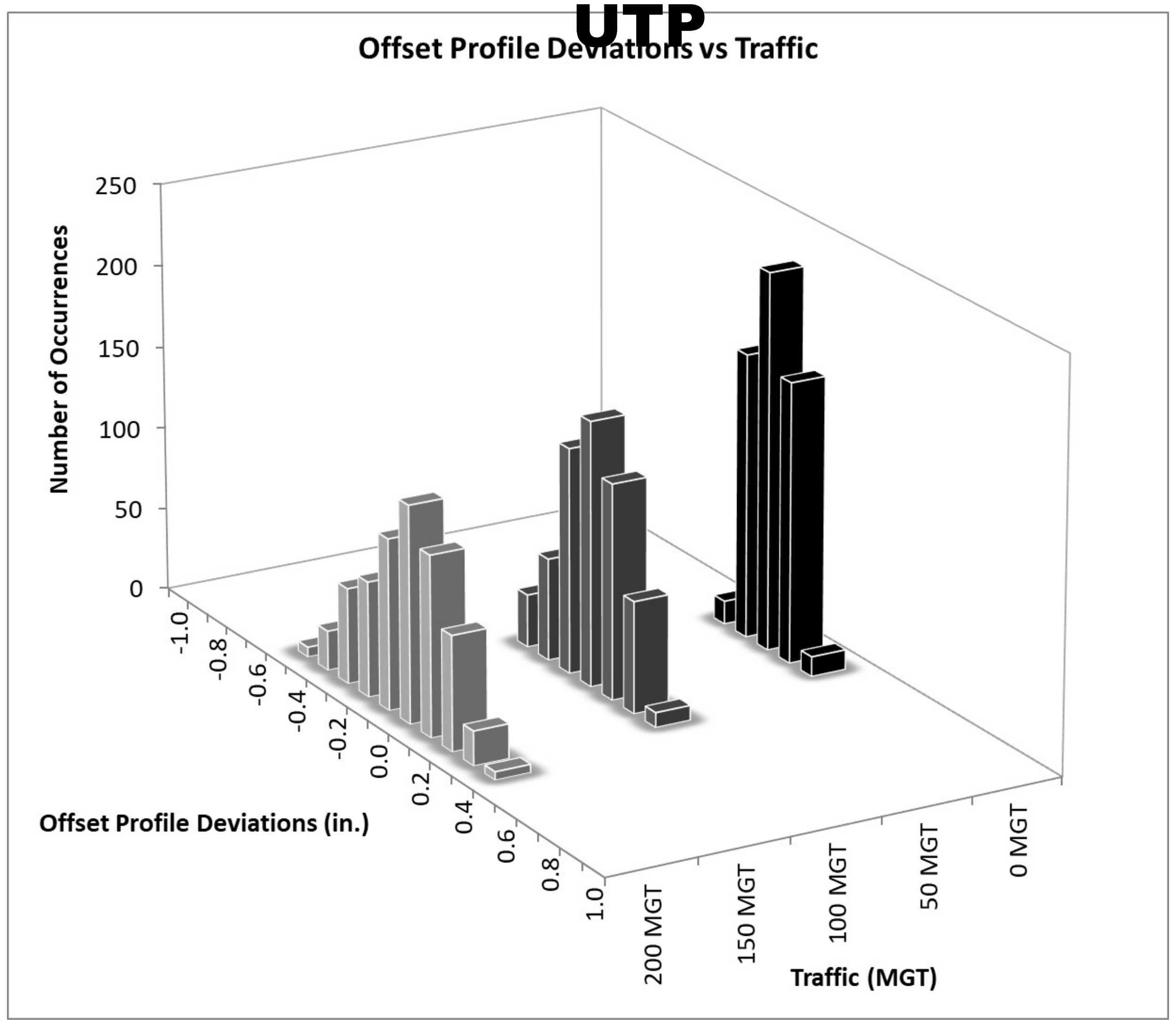


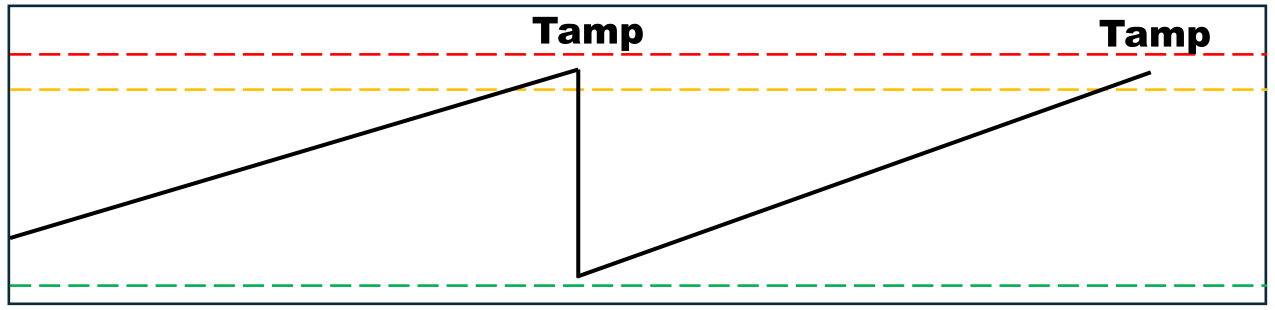
Roughness



Tamping intervals extended by a **factor of three**

Concrete equipped with UTP





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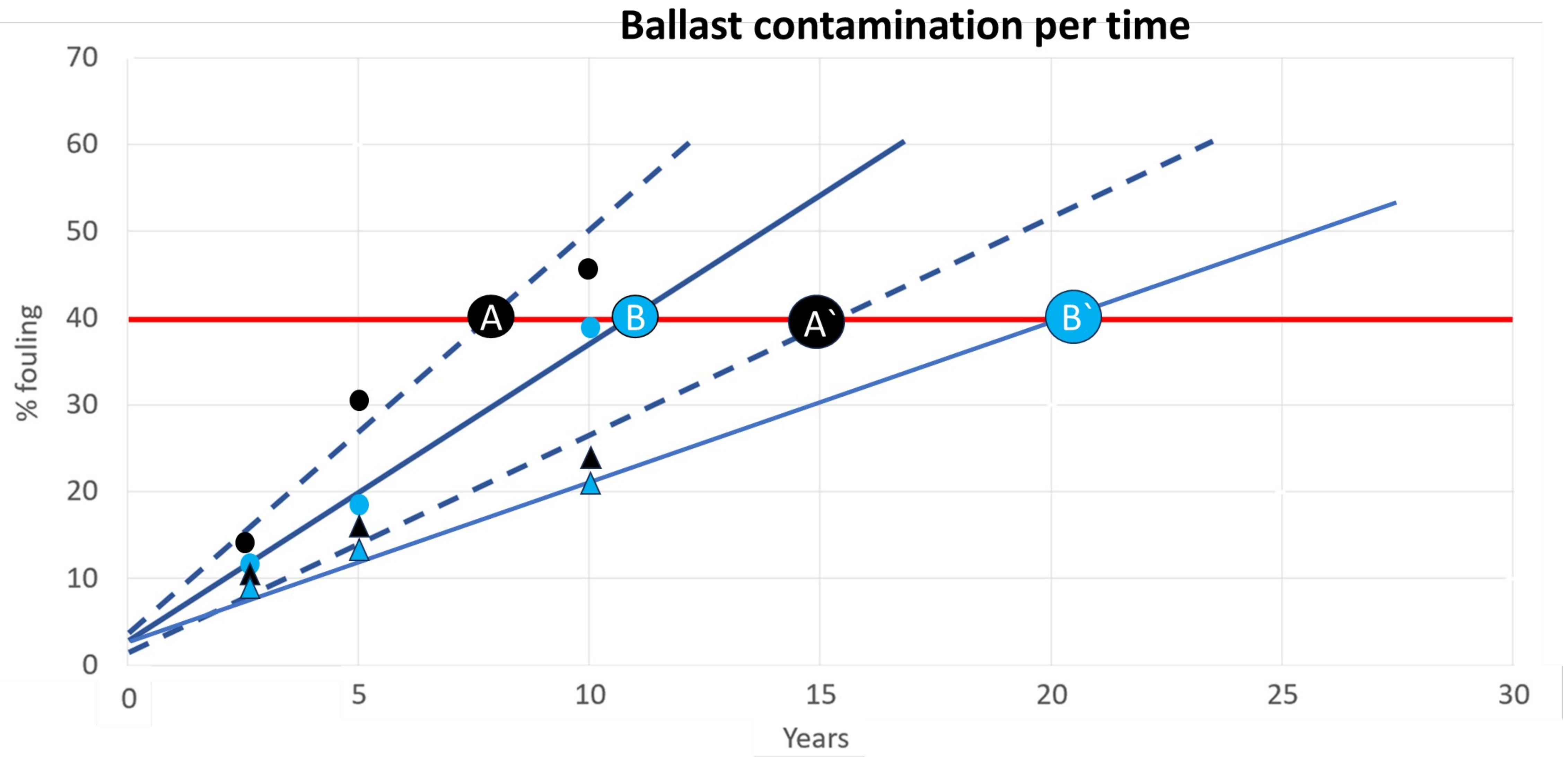
The use of UTP in MRS - 10 years experience



Variables:

- **The use of UTP**
- **Subgrade stiffness**

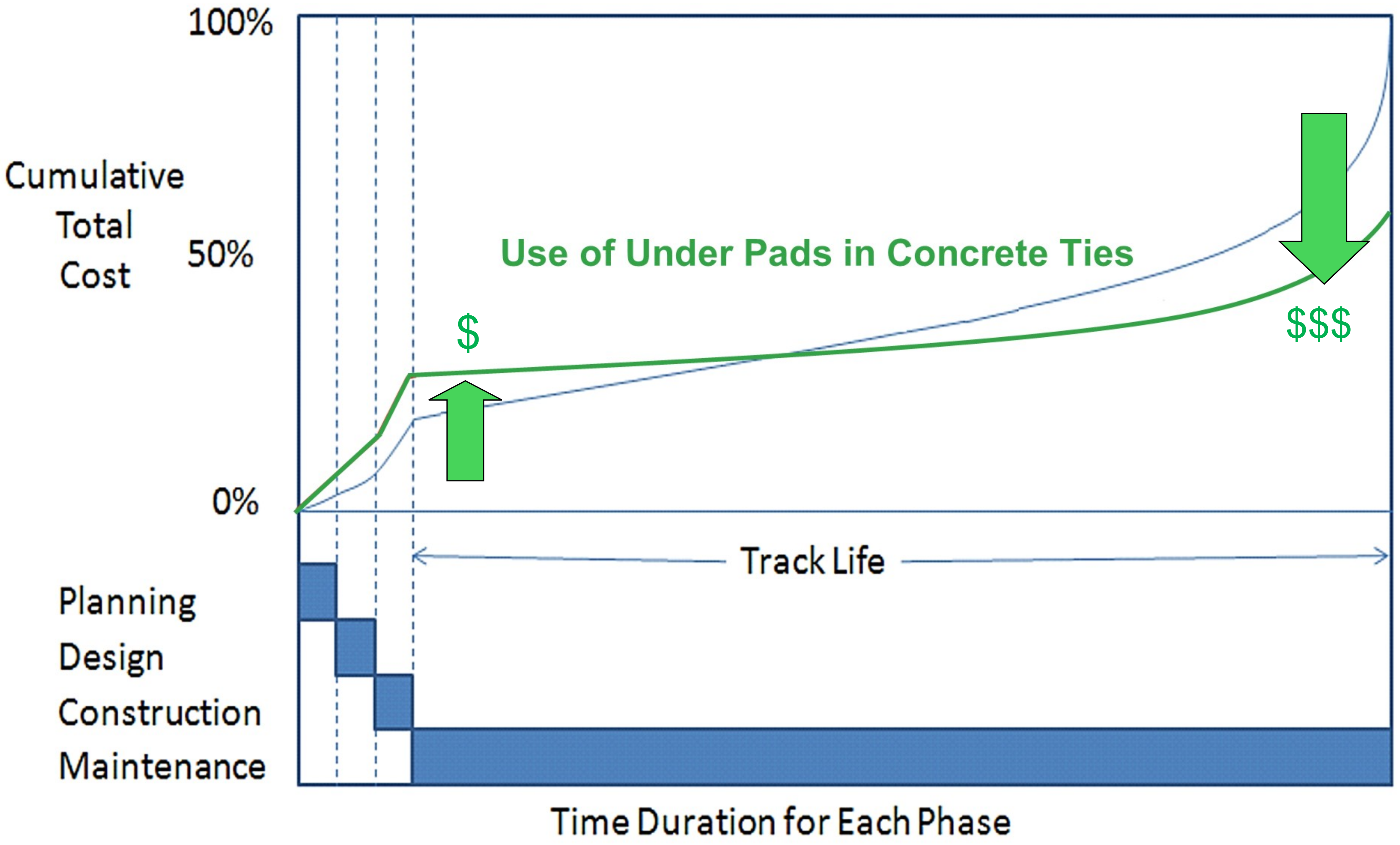
A
180 MGT/year
32 tons/axle
Concrete tie
Granite-gneiss ballast
Weak subgrade

B
180 MGT/year
32 tons/axle
Concrete tie
Granite-gneiss ballast
Solid subgrade

A`
180 MGT/year
32 tons/axle
Concrete tie + UTP
Granite-gneiss ballast
Weak subgrade

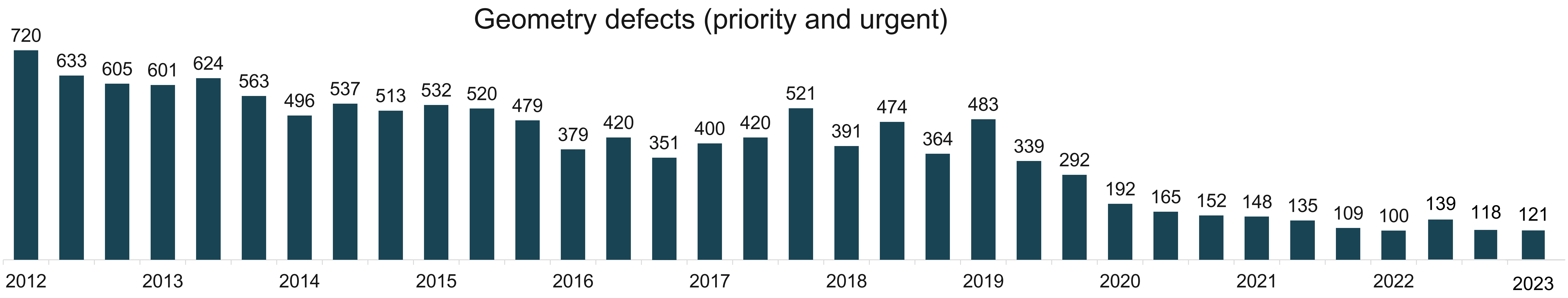
B`
180 MGT/year
32 tons/axle
Concrete tie + UTP
Granite-gneiss ballast
Solid subgrade

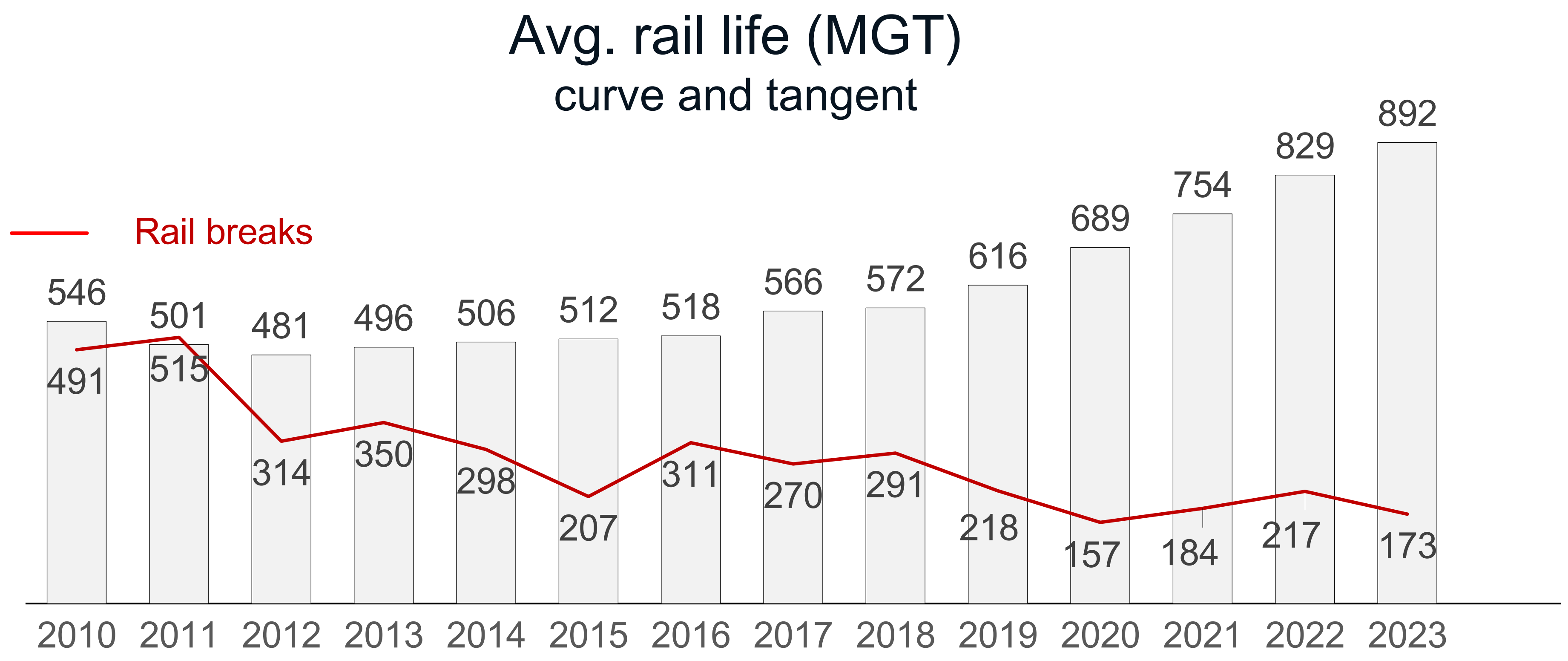
LIFE-CYCLE COST CONSIDERATIONS

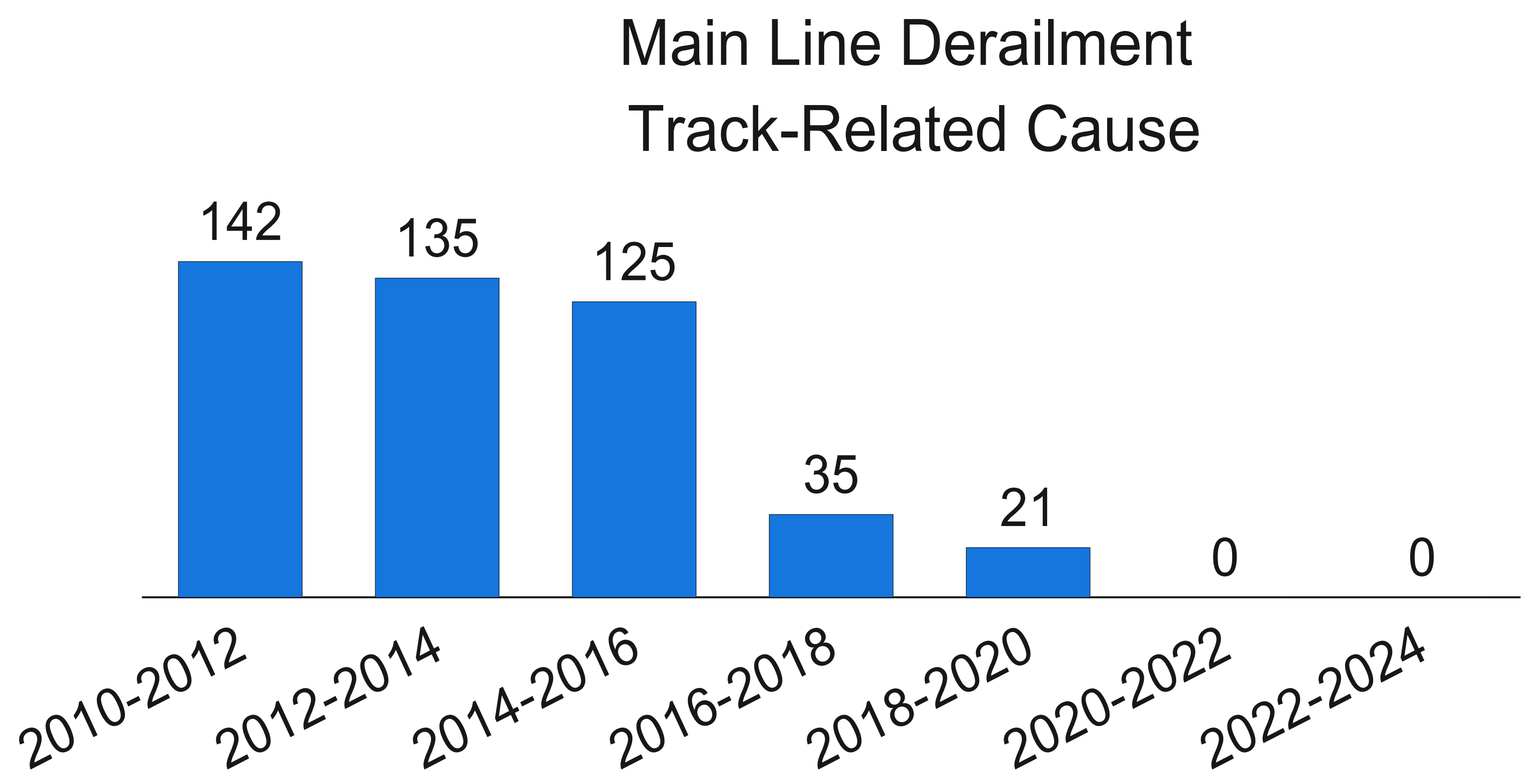


- **Consider long-term performance, not just initial costs.**
- **Reduces track maintenance by up to 3×.**
- **ROI estimated in 3–8 years, depending on traffic.**
- **UTPs are most cost-effective on high-traffic sections and tight curves.**

Results of a Successful Maintenance Strategy







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JUNE 10-12, 2025

Conclusions

Introducing appropriate elasticity into the system reduces degradation of track components.

Resilient pad in steel plates helped reduce rail base fractures on wooden ties, especially in rigid zones and high support variation locations.

Use of resilient rail pads mitigated RSA on concrete ties (over 1,600 MGT accumulated).

UTPs on concrete ties:

- Reduced tamping cycles from 2 to 3×, depending on the asset.
- Potential to delay undercutting by up to 8 years.
- Extends crosstie service life by up to 5 years, reducing early failures.
- Increases the lifespan of system components by up to 20%, depending on section characteristics.

Next Steps:

- Potential reduction of the granular layer thickness

Register toda

IHHA/WCRR Rail Research Wee
at the Broadmoor, Colorado Sp
Hosted by MxV Rail.

MRS Logística S.A.

Thank you!