Graz University of Technology
Institute for Railway Engineering and Transport Economy

Technical and economical considerations of padded concrete sleepers in the Austrian network

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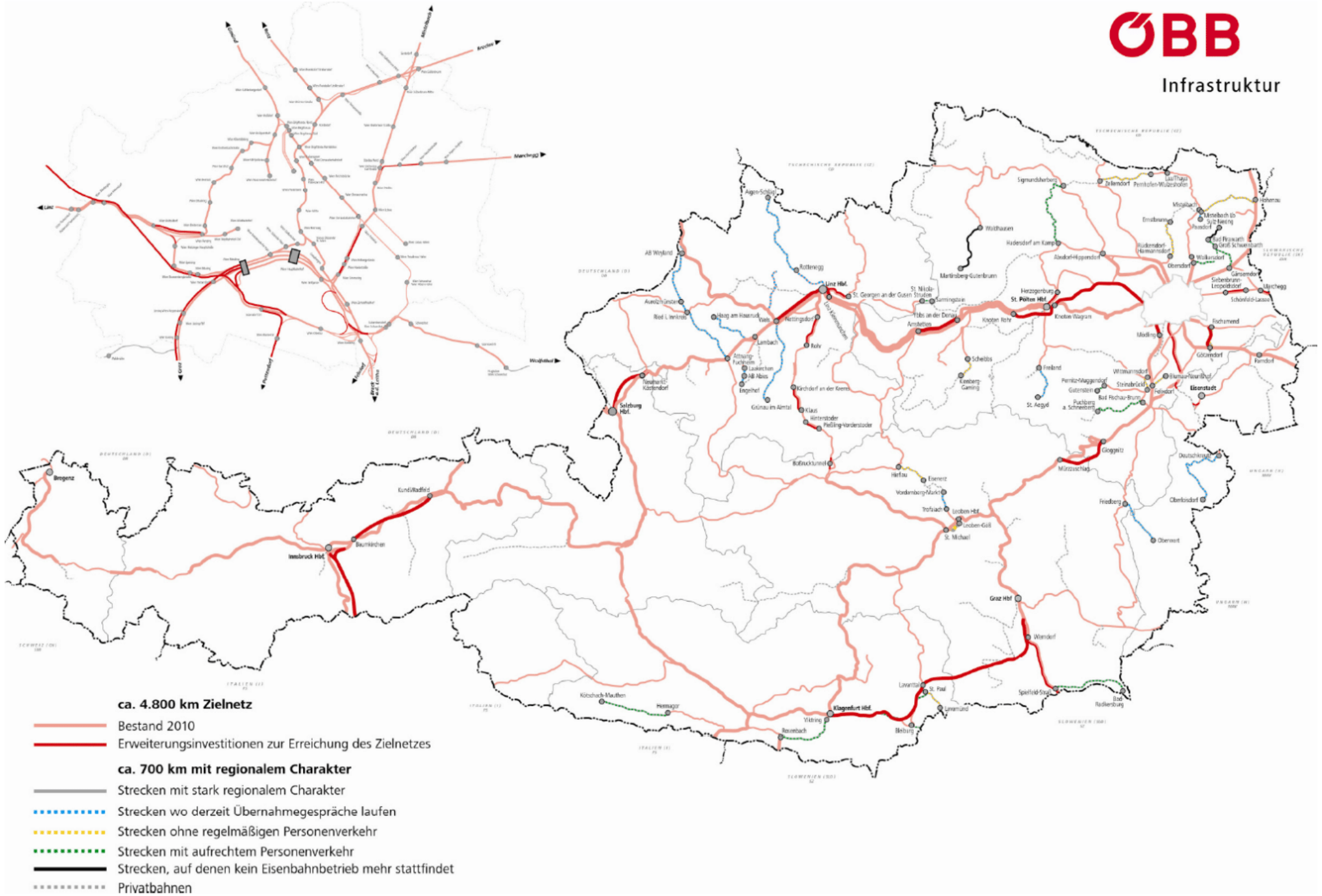
Agenda

- Characteristics of the Austrian railway network
- Technical performance of concrete sleepers with pads (USP)
- Economical performance of concrete USPs

The Austrian network

The Austrian network

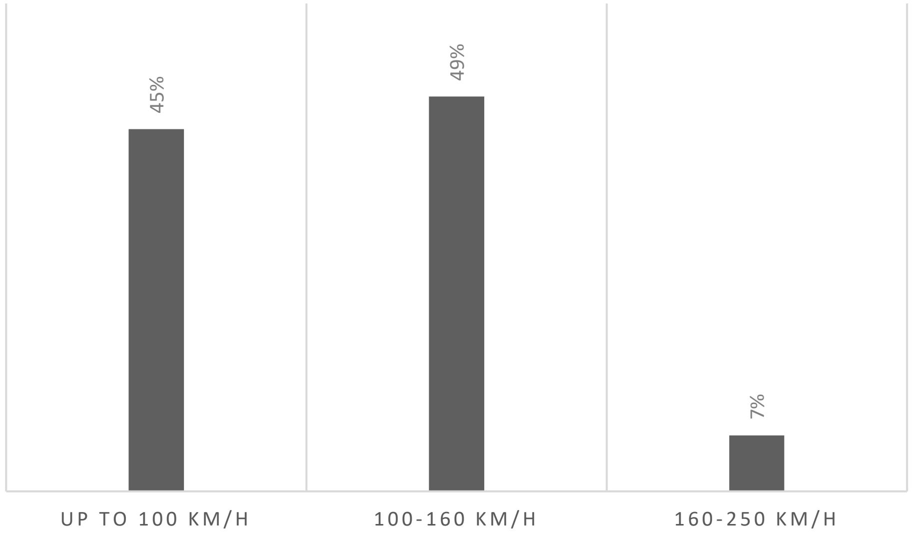


- 9,748 km of track
- 12,919 turnouts included
- 6,634 bridges
- 259 tunnels

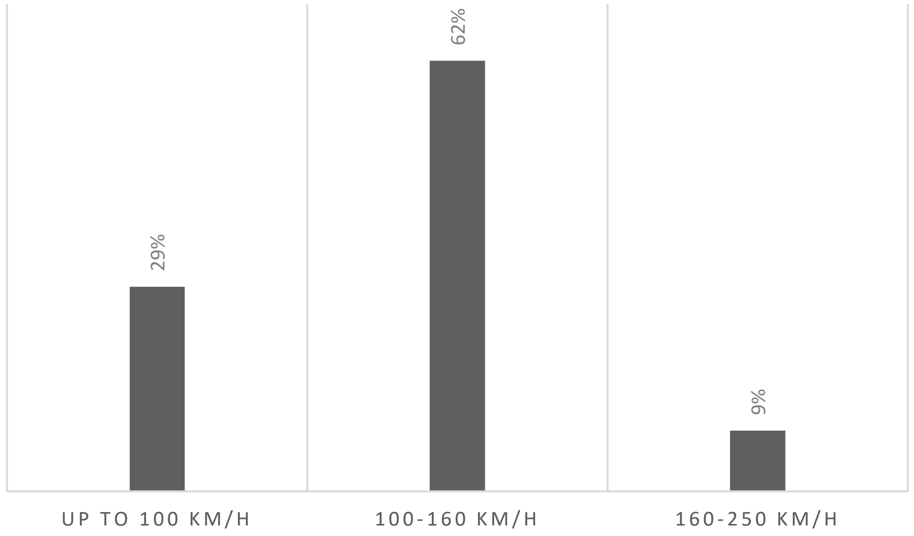
- 117 Mio train km in passenger and
- 40 Mio track km in freight traffic
- Track design: max 250 km/h
- Operation speed: 230 km/h

Source:ÖBB

Permitted speed levels in the Austrian network



Entire network

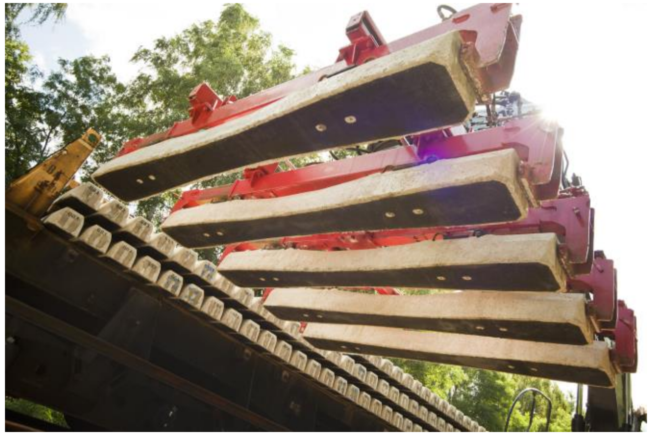


Main network, main tracks

Sleeper types in the Austrian network

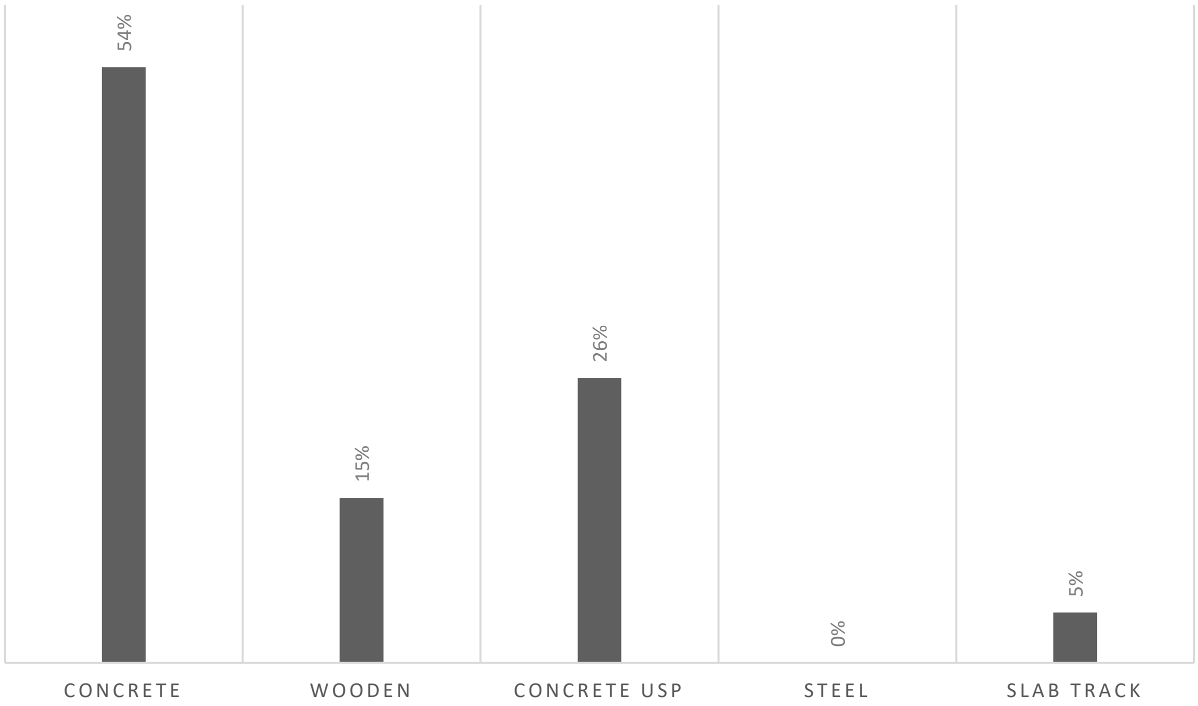
Wooden sleeper

Concrete sleeper



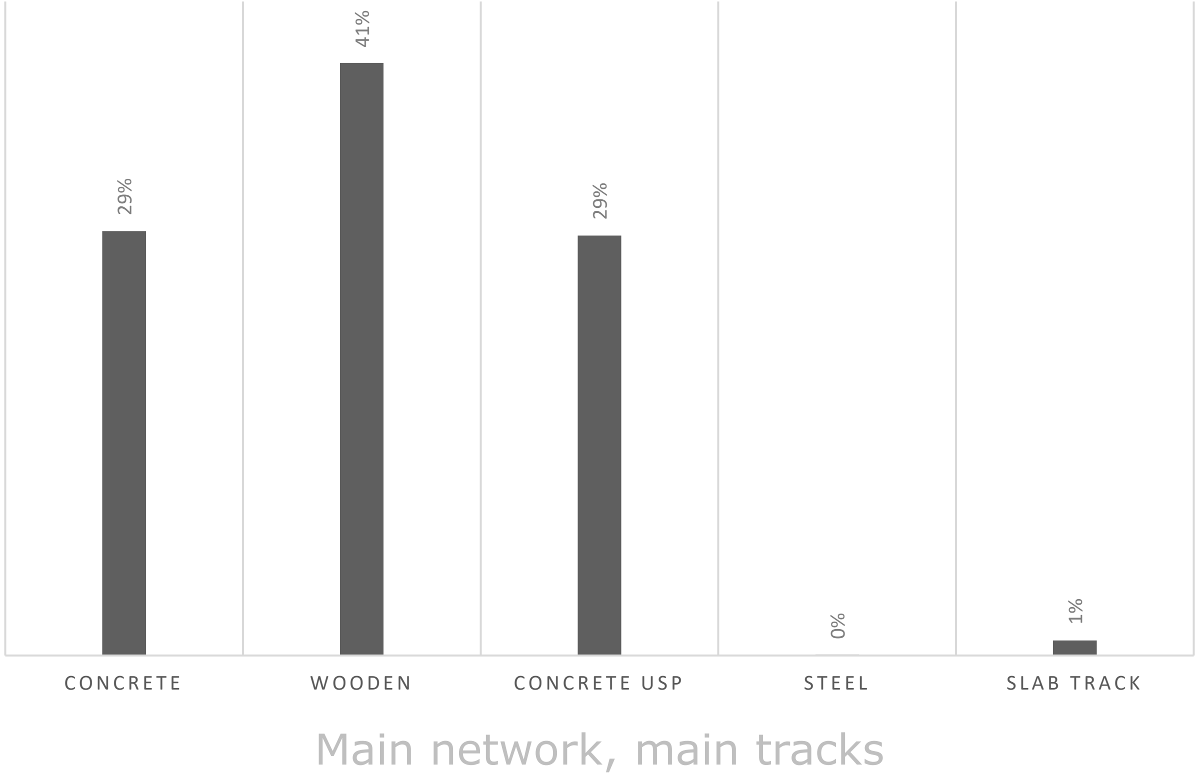
Concrete USP sleeper

Sleeper types in the Austrian network – Track



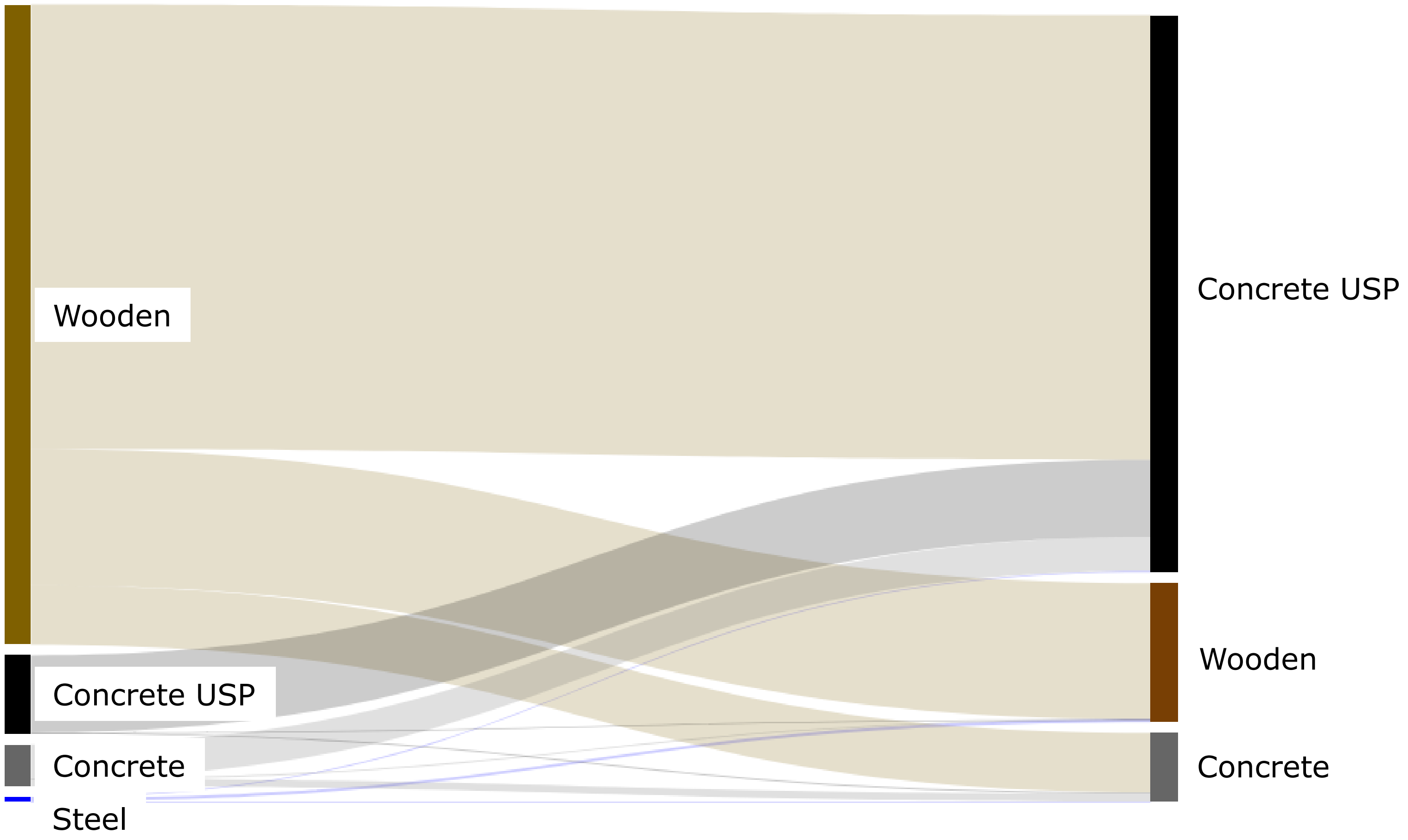
Main network, main tracks

Sleeper types in the Austrian network – Turnouts



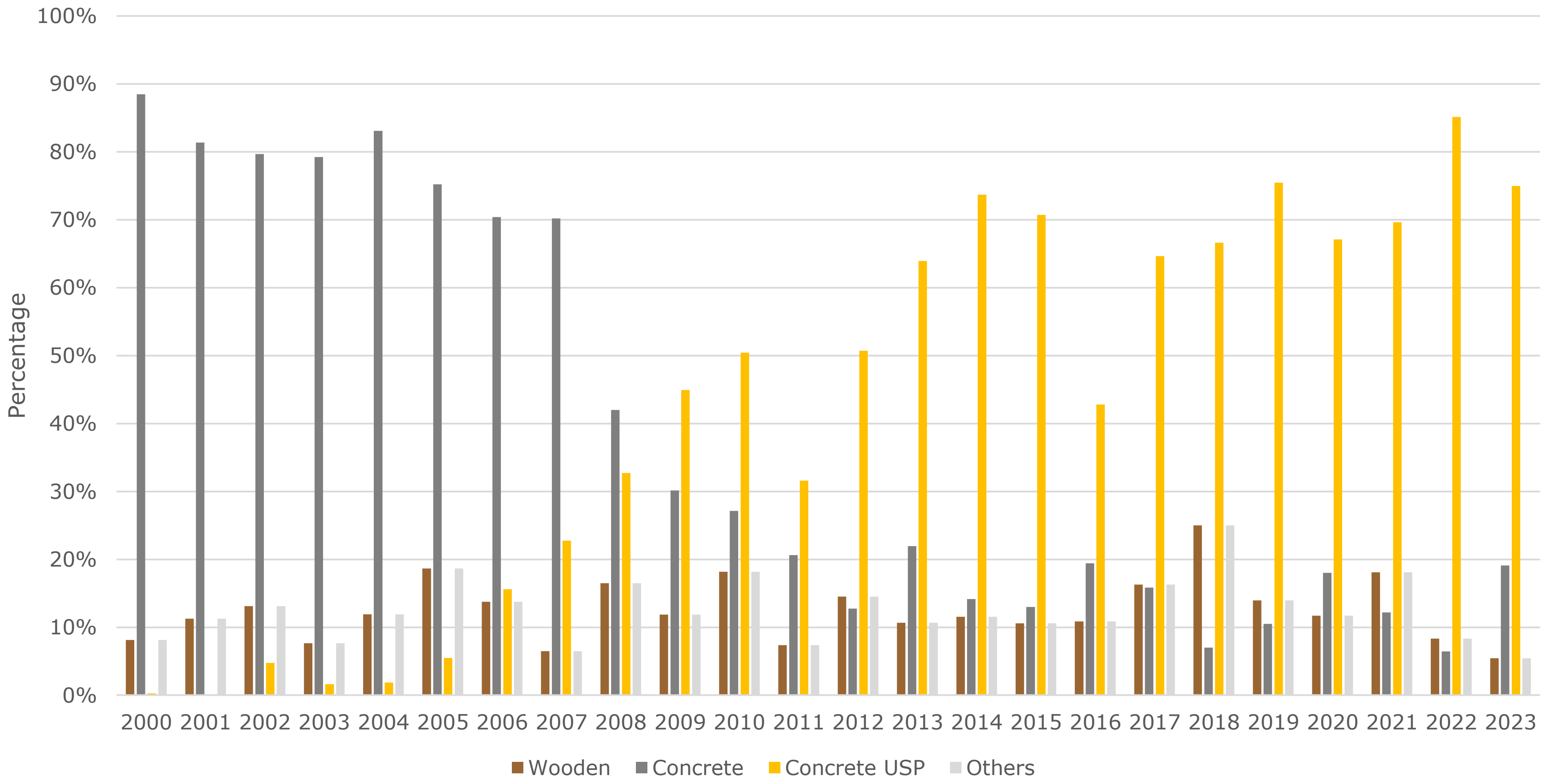
Turnout renewals 2017-2022: Choice of sleeper types

Main network, main tracks



Track renewals 2000-2023: Choice of sleeper types

Main network, main tracks



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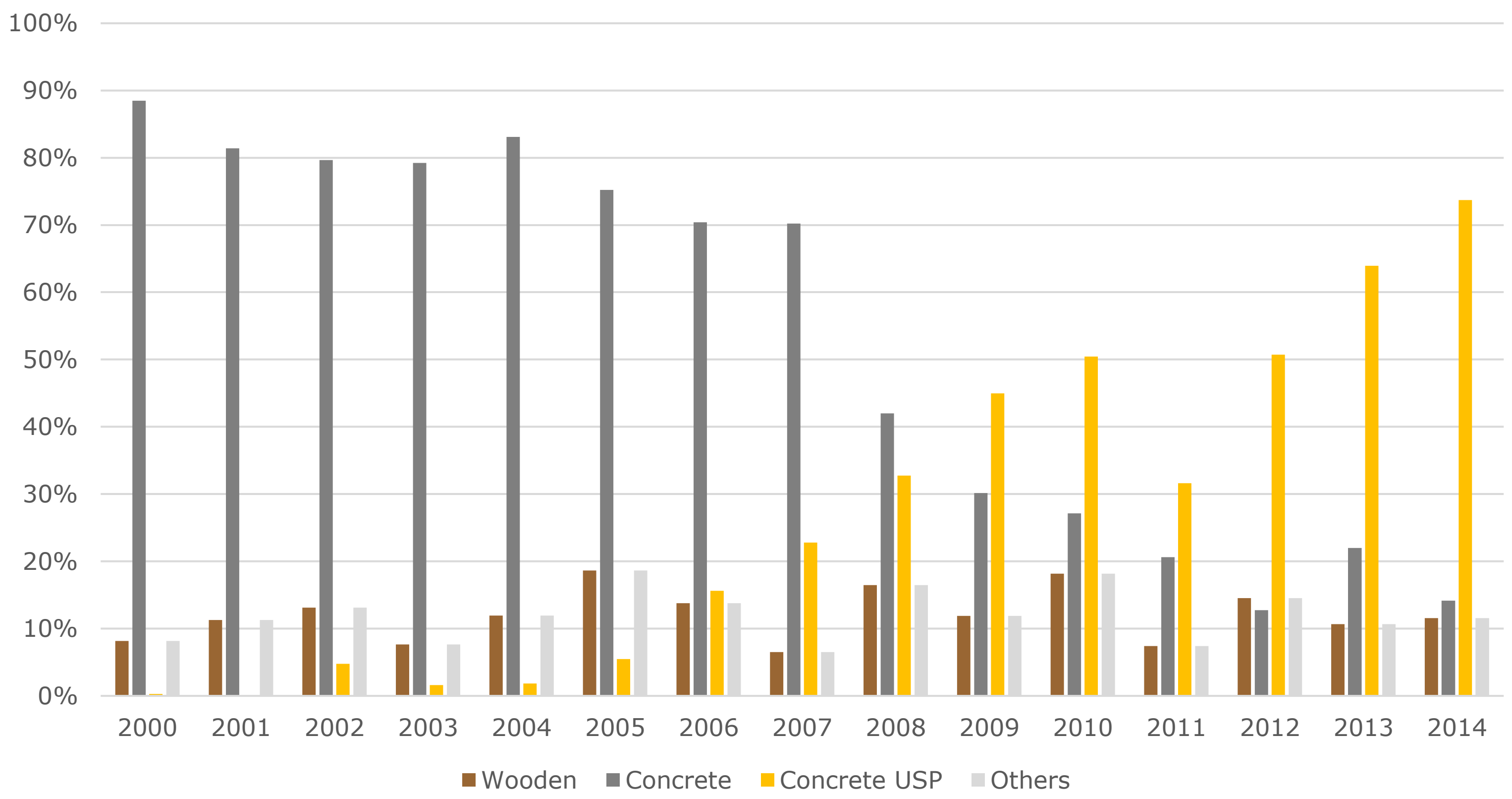
Technical performance of concrete USPs

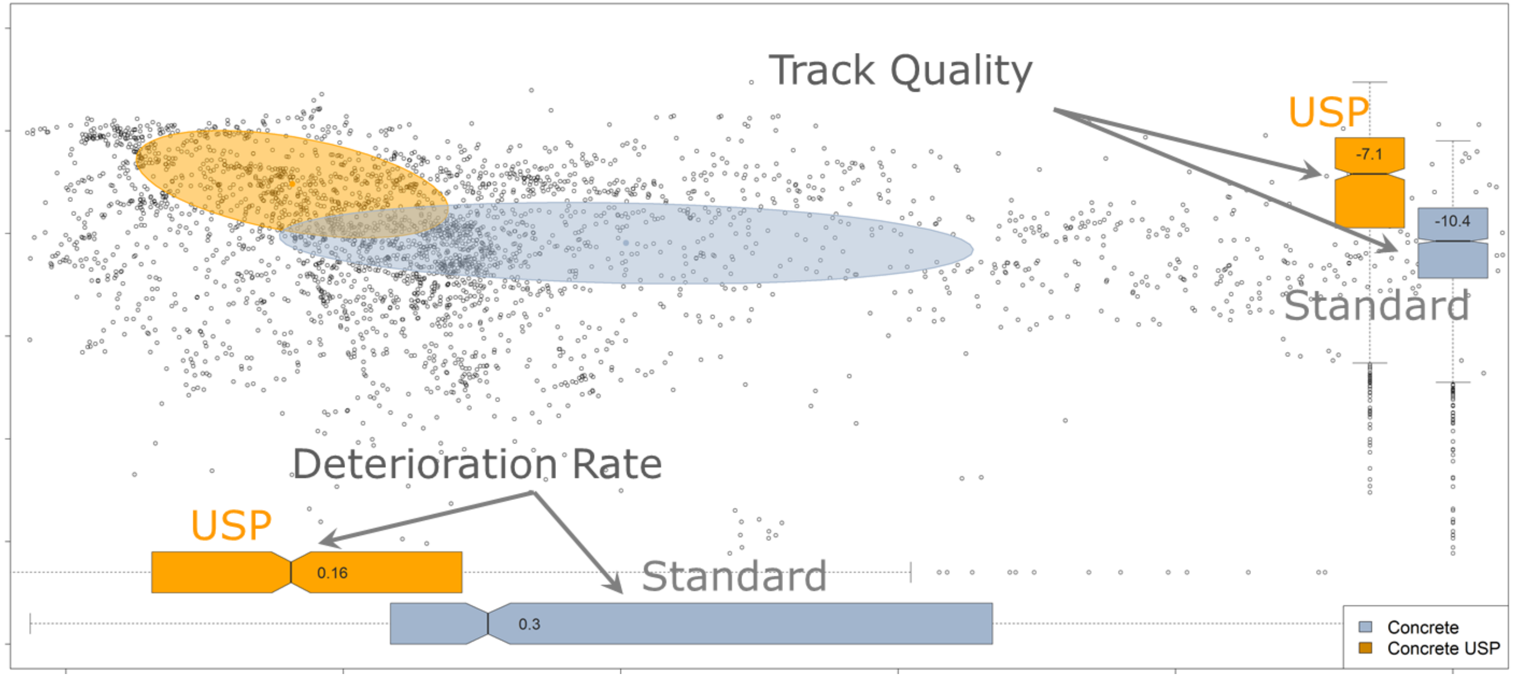
Under Sleeper Pads – Field Experience (2014)

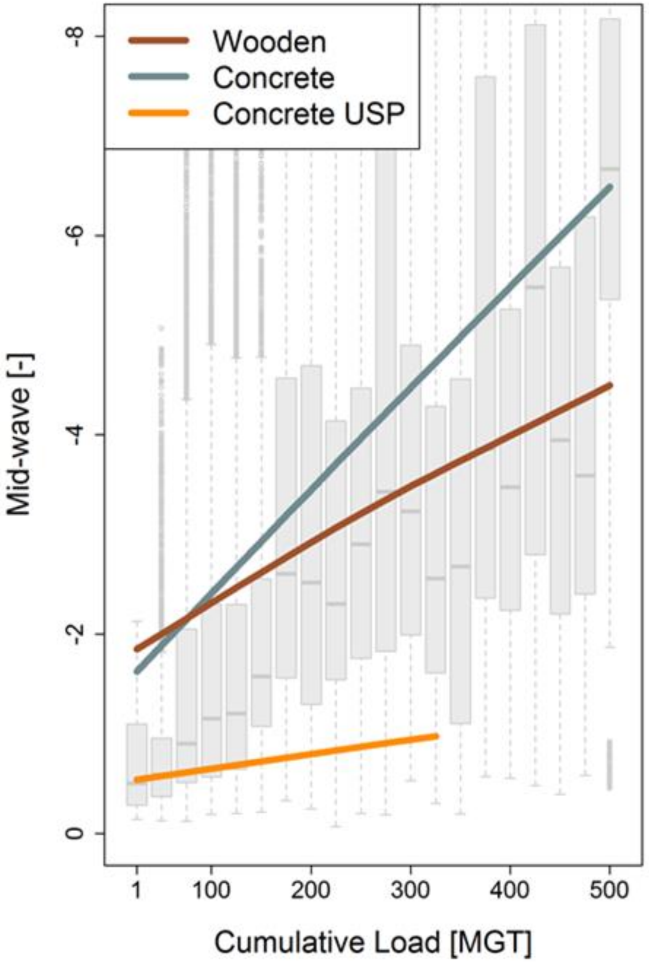
The last in-depth evaluation was performed in 2014. 50,000 cross-sections analysed



Under Sleeper Pads – Field Experience (2014)

The last in-depth evaluation was performed in 2014. 50,000 cross-sections analysed
→ USPs perform perfectly





Under Sleeper Pads – A further perspective (2024)

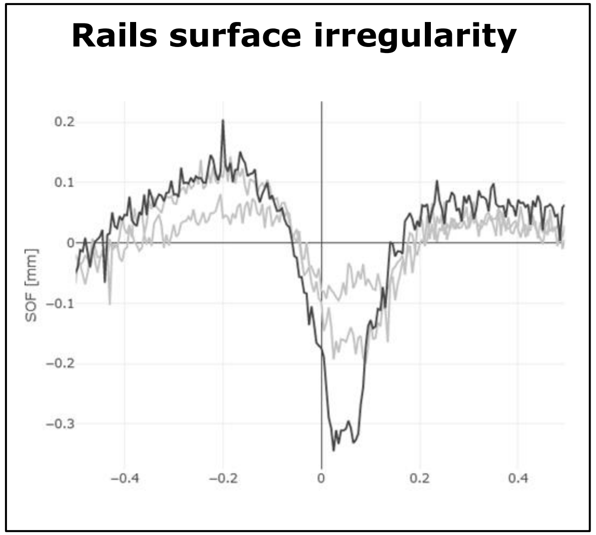
Dipl.-Ing. Markus Loidolt, BSc

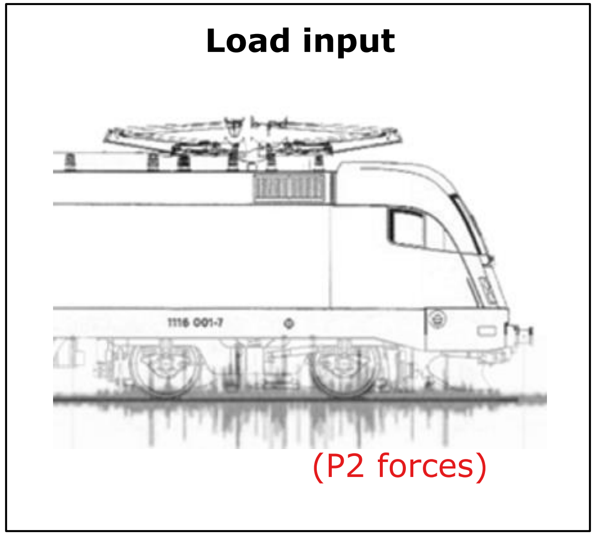
Integration of Short-Wave Effects into Asset Management of Railway Infrastructure
An alternative perspective on the quality behaviour of tracks

DOCTORAL THESIS

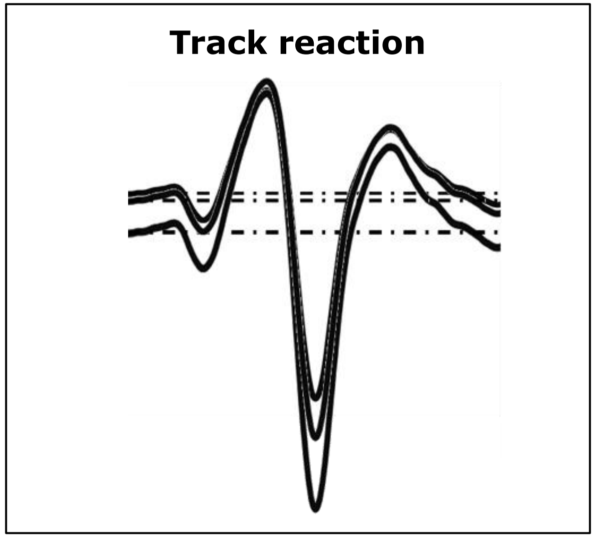
to achieve the university degree of
Doktor der technischen Wissenschaften

Rail surface irregularities - damage principle:





Track characteristics:
Stiffness, damping
Vehicle characteristics:
(unsprung) mass, V



Track characteristics:
Components, subsoil, elasticity, load-bearing capacity

The rail surface measurement system (rail corrugation system)

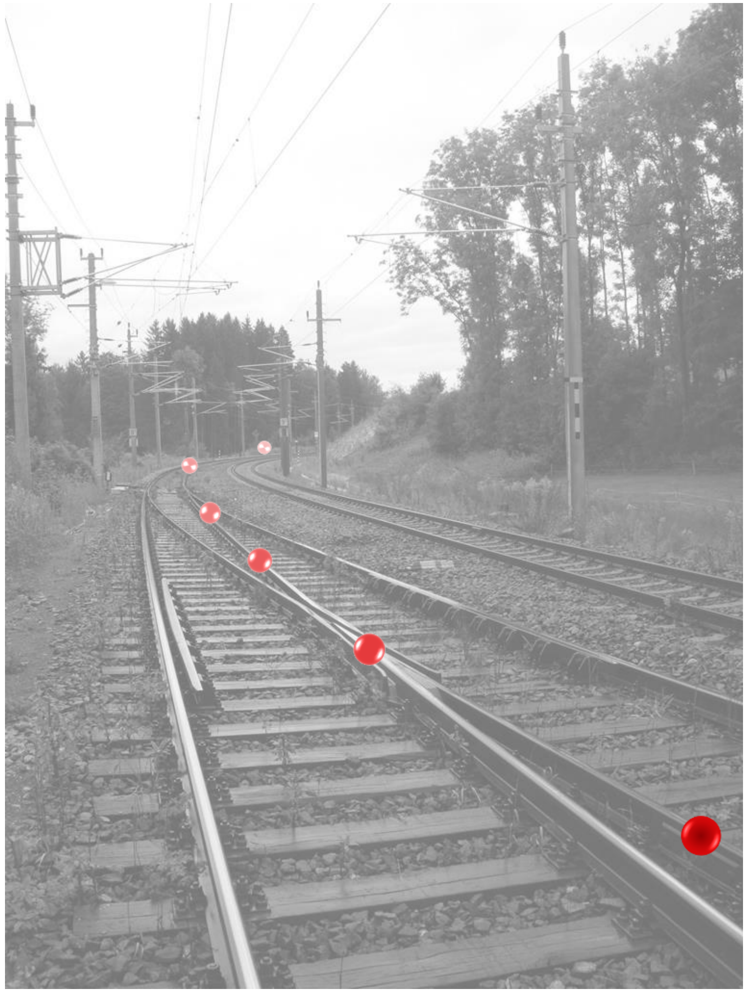
Sampling Rate: 5 mm
Measuring speed: 250 km/h
Wavelength range: 20-1000 mm

The rail surface measurement system (rail corrugation system)

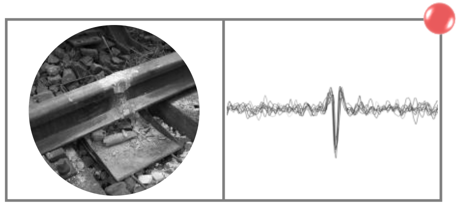
Skid marks

Squat detection

Turnout components

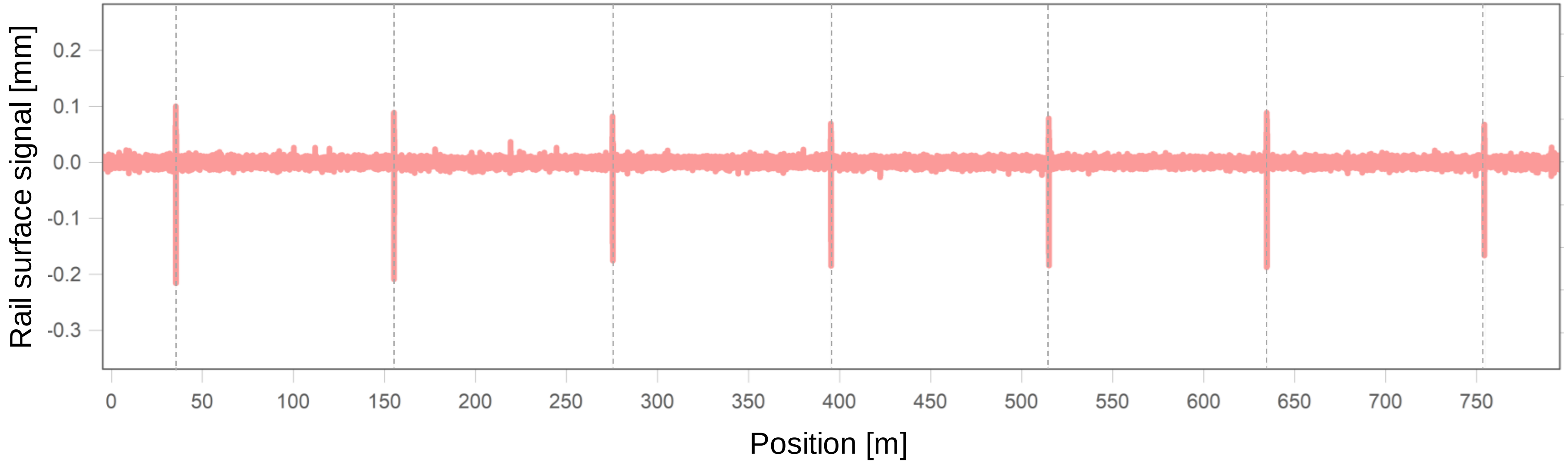


Rail corrugations

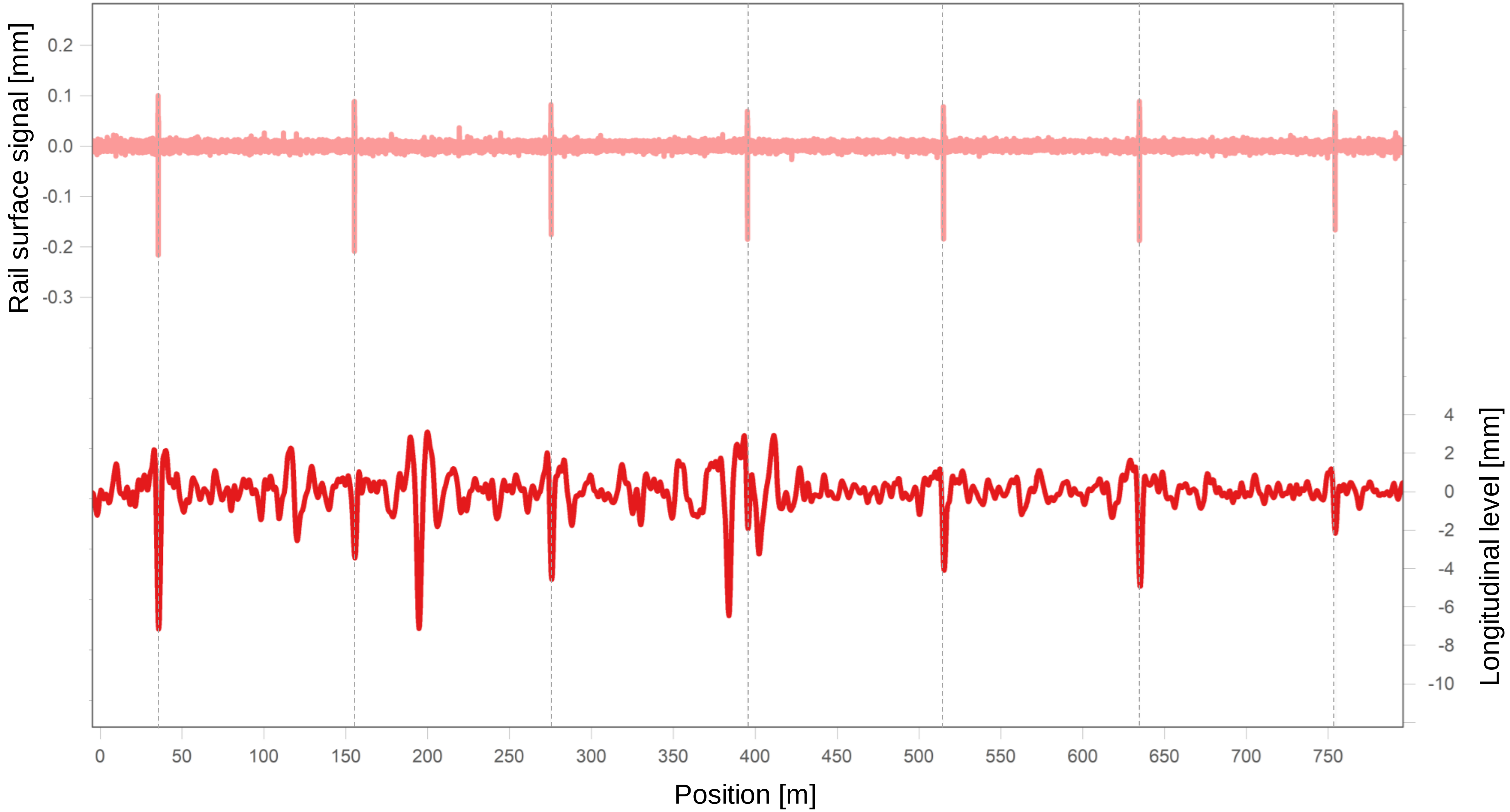

Welded joints

Insulated rail joints

The role of welded joints in track deterioration

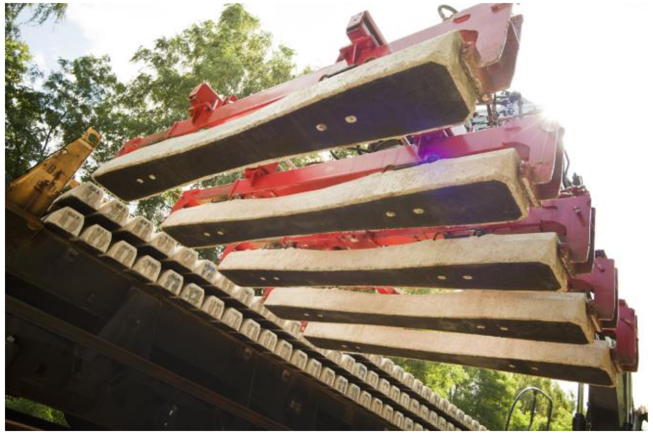


The role of welded joints in track deterioration



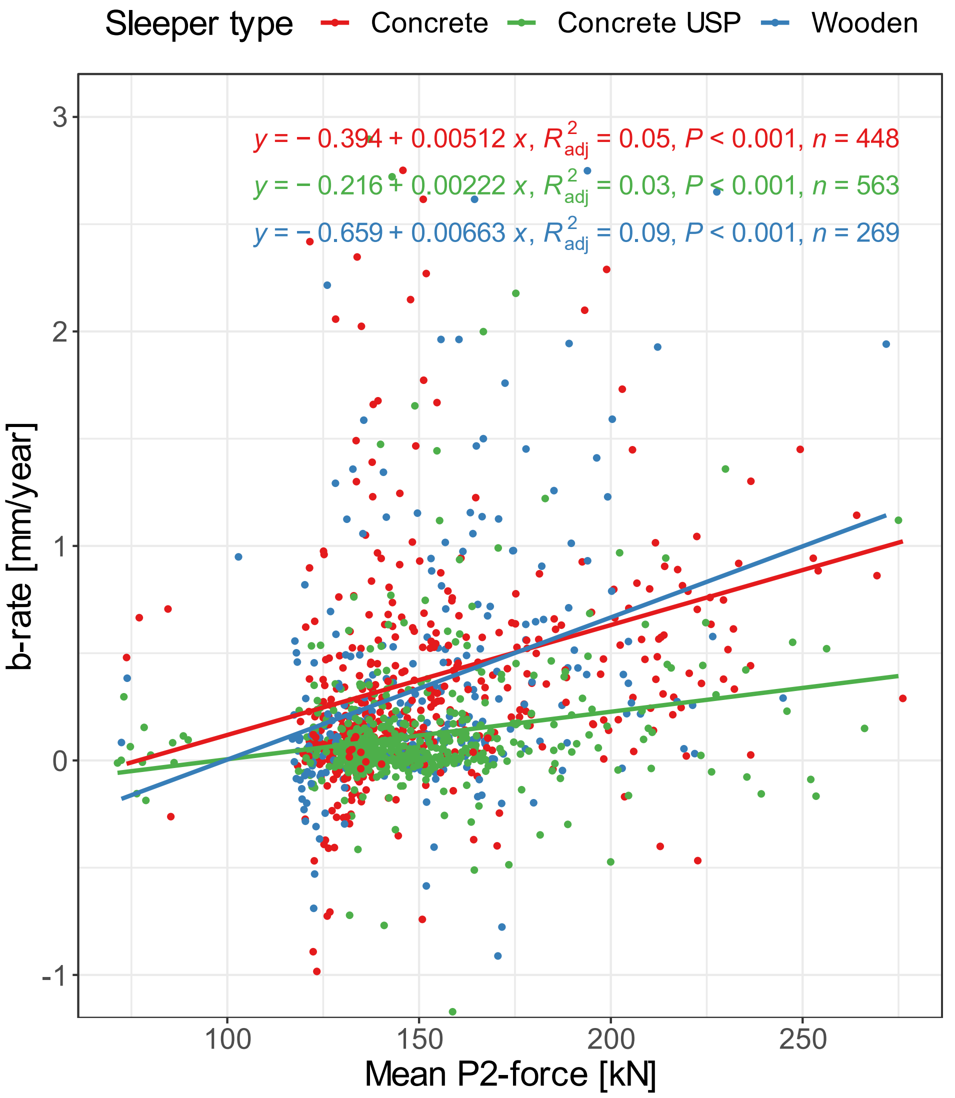
The role of welded joints in track deterioration: Sleeper types

Concrete sleeper

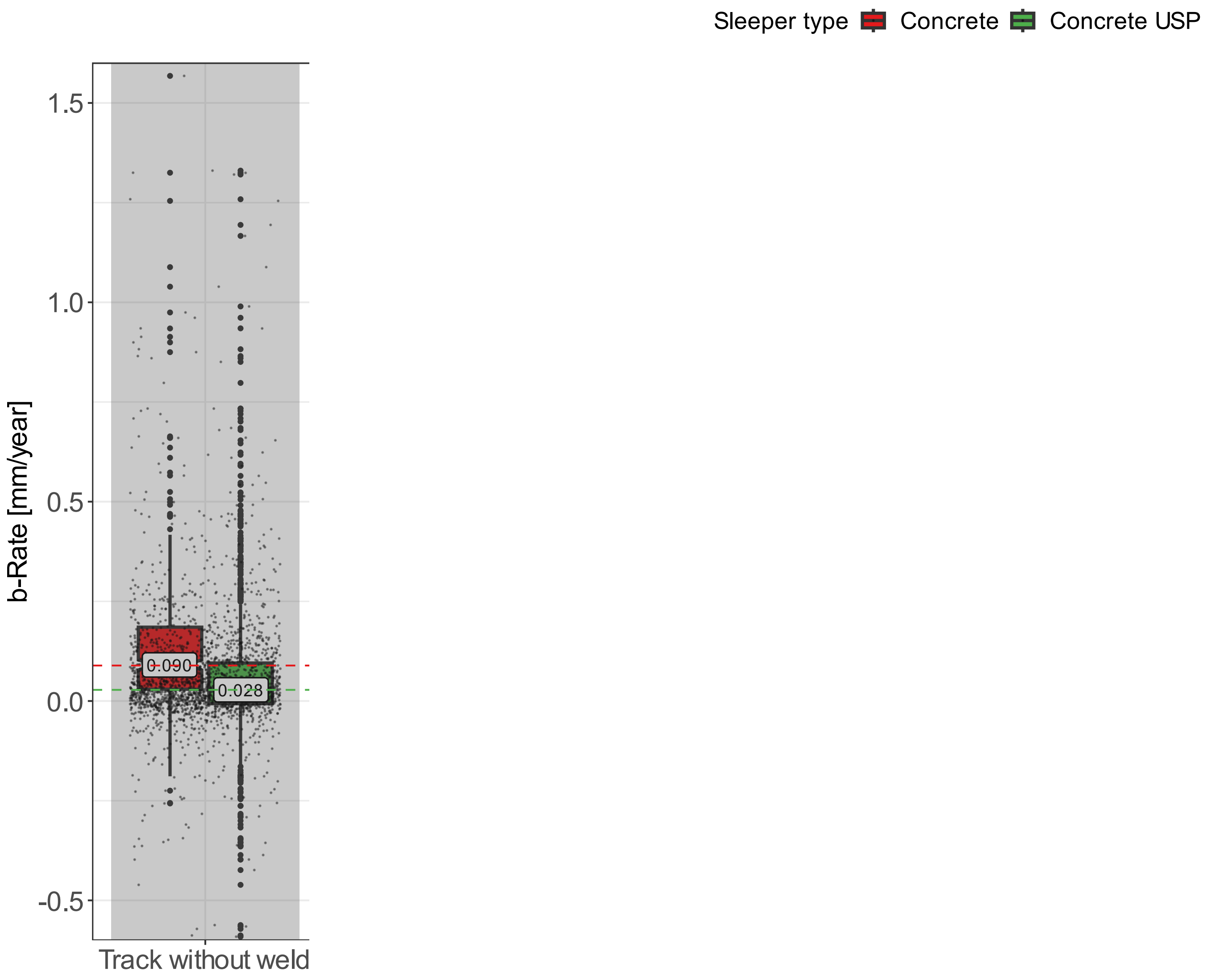


Concrete USP sleeper

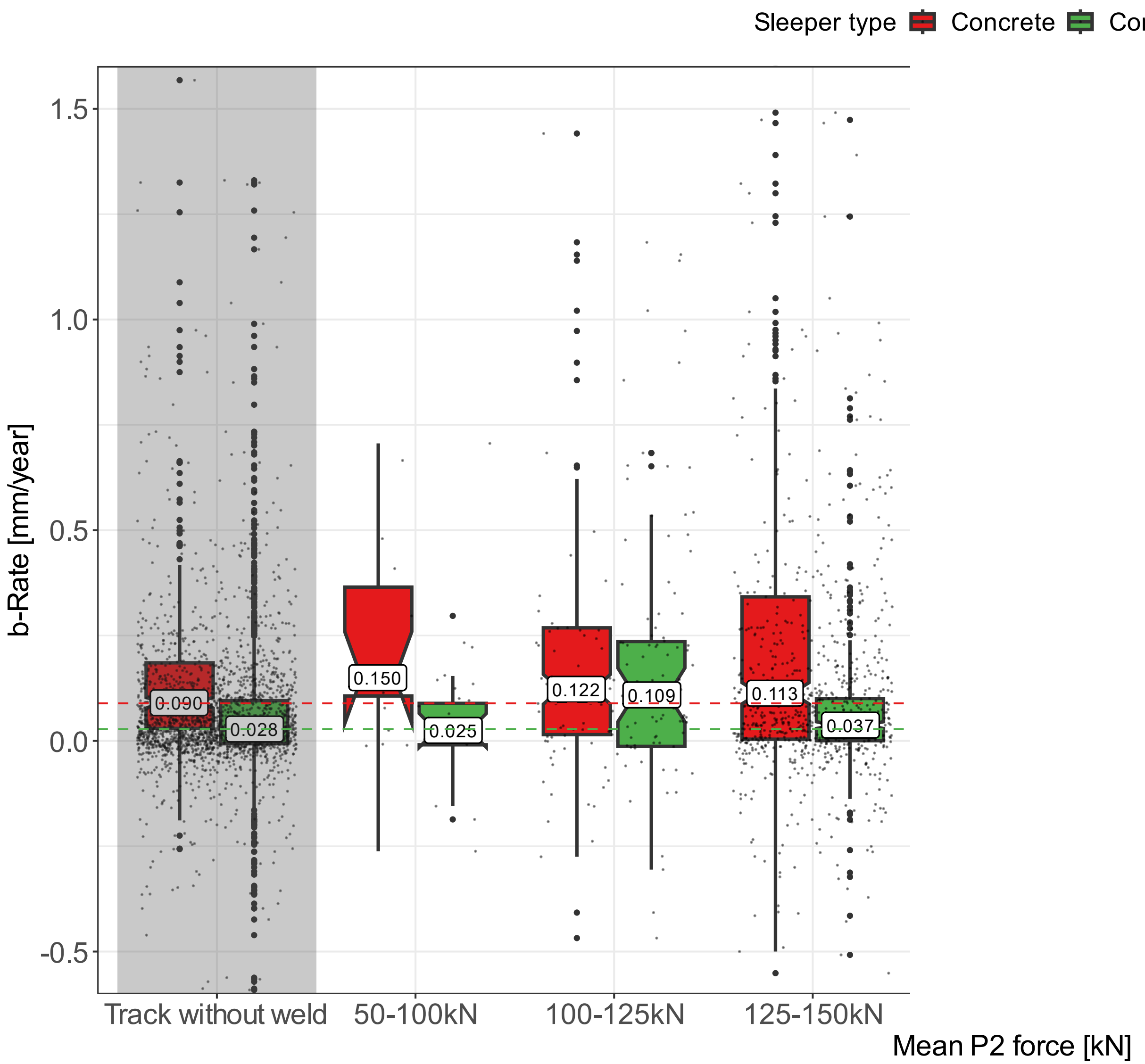
The role of welded joints in track deterioration: Sleeper types



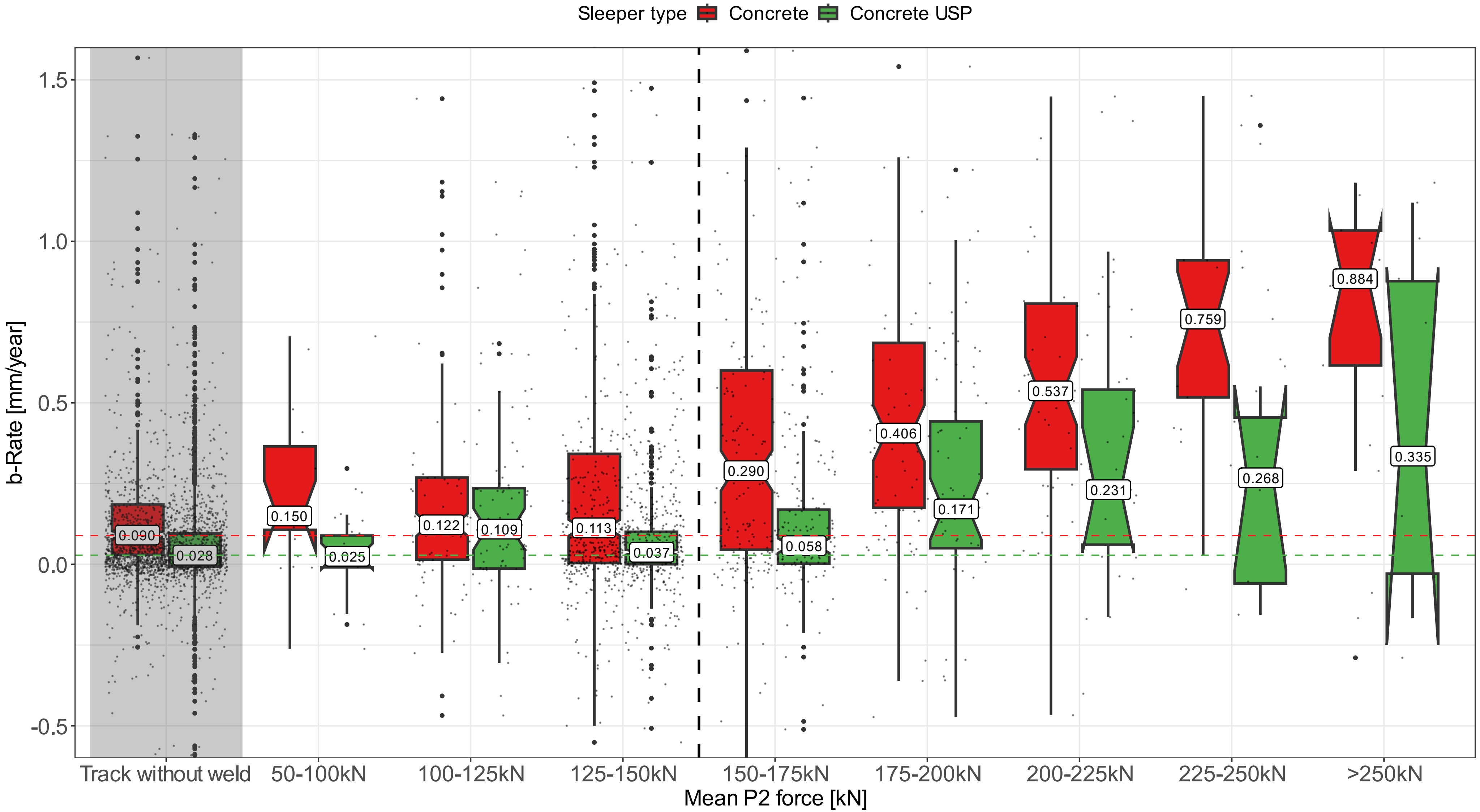
Performance of concrete and concrete USP under dynamic loading



Performance of concrete and concrete USP under dynamic loading

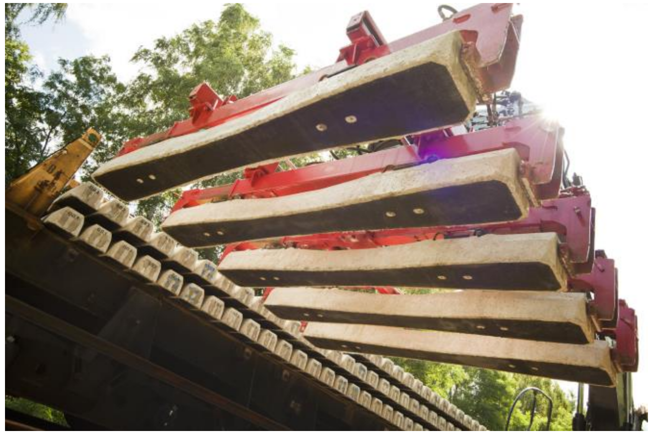


Performance of concrete and concrete USP under dynamic loading



The role of welded joints in track deterioration: Impact of sleeper types

Concrete sleeper



Concrete USP sleeper

Under sleeper pads pads
significantly improve resistance
to dynamic loading!

Conclusion after over 20 years of experience with USPs

Concrete sleepers with under sleeper pads perform extremely well in all the technical aspects analysed so far!

What about the economics?

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Economical performance of concrete USPs

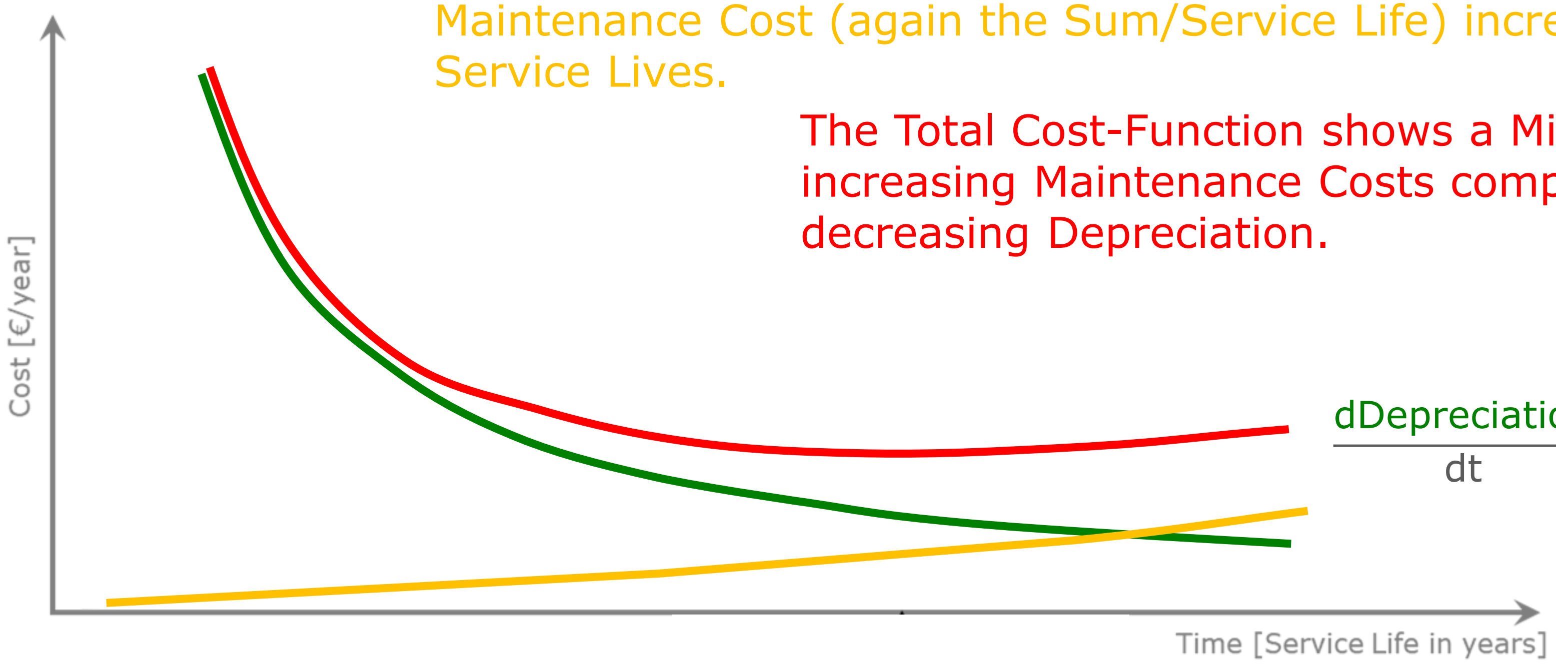
Asset Management | Goal: cost-efficient Assets

We calculate Life Cycle Cost in order to find out the economic Service Life!

The Calculatory Depreciation is a 1/n-Function. The Investment Cost are always divided by the already realised Service Life.

Maintenance Cost (again the Sum/Service Life) increase with higher Service Lives.

The Total Cost-Function shows a Minimum, where the increasing Maintenance Costs compensate the decreasing Depreciation.

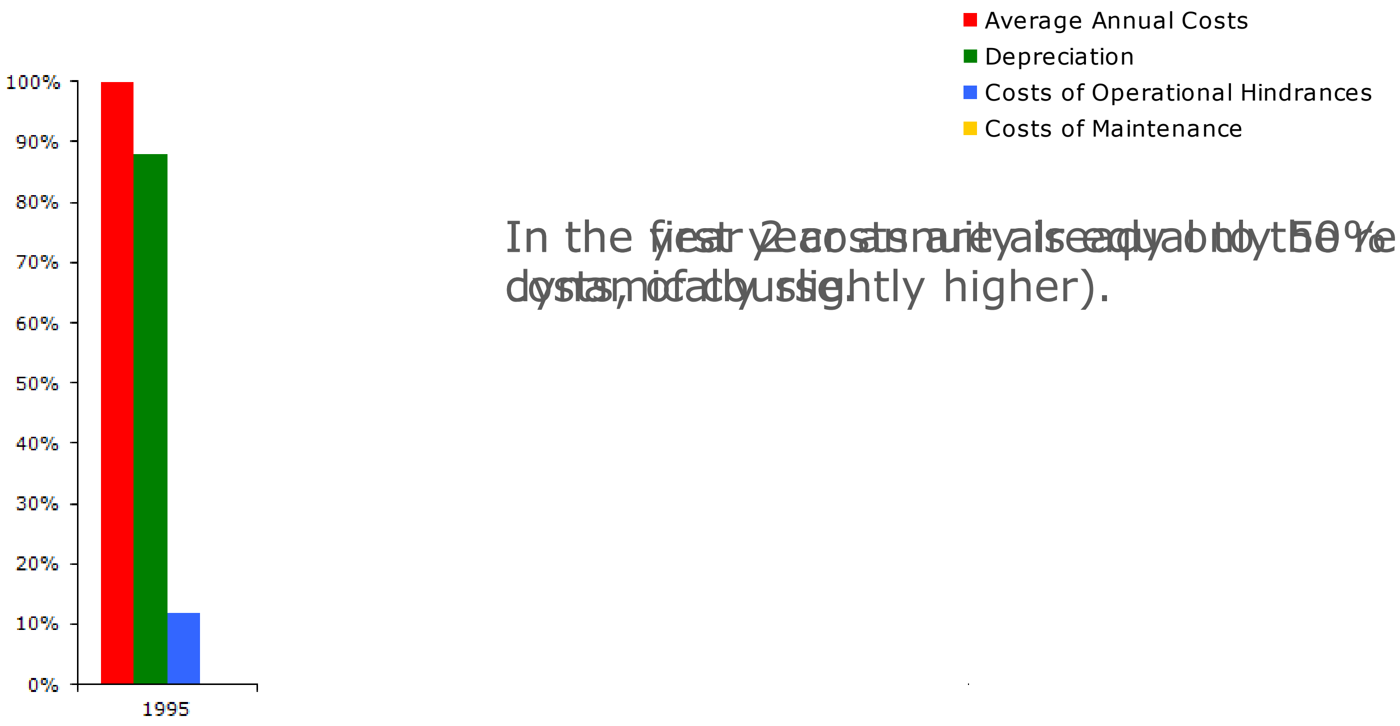


$$\frac{\text{dDepreciation}}{\text{dt}} \equiv \frac{\left(\frac{\text{dMaintenance Costs}}{\text{year}}\right)}{\text{dt}}$$

Annuity Monitoring

"Südbahn"	400<R<600	zweigleisig		
GesBT/Tag, Gleis	Profil	Güte	Unterbau	Schwelle
42.189	60E1	260	gut	Beton

Instandhaltungsarbeit	ND in Jahren	1,0	1995	1996
Re-Investition (SUZ/AHM)		1,0	1	
Stopfen	alle x Jahre	0,0		1
Schleifen	Anzahl in ND	1,0	1	
Schienenwechsel	Anzahl in ND	0,0		
Zwischenlagenwechsel	Anzahl in ND	0,0		
Mängelbehebung	Anzahl in ND	-		

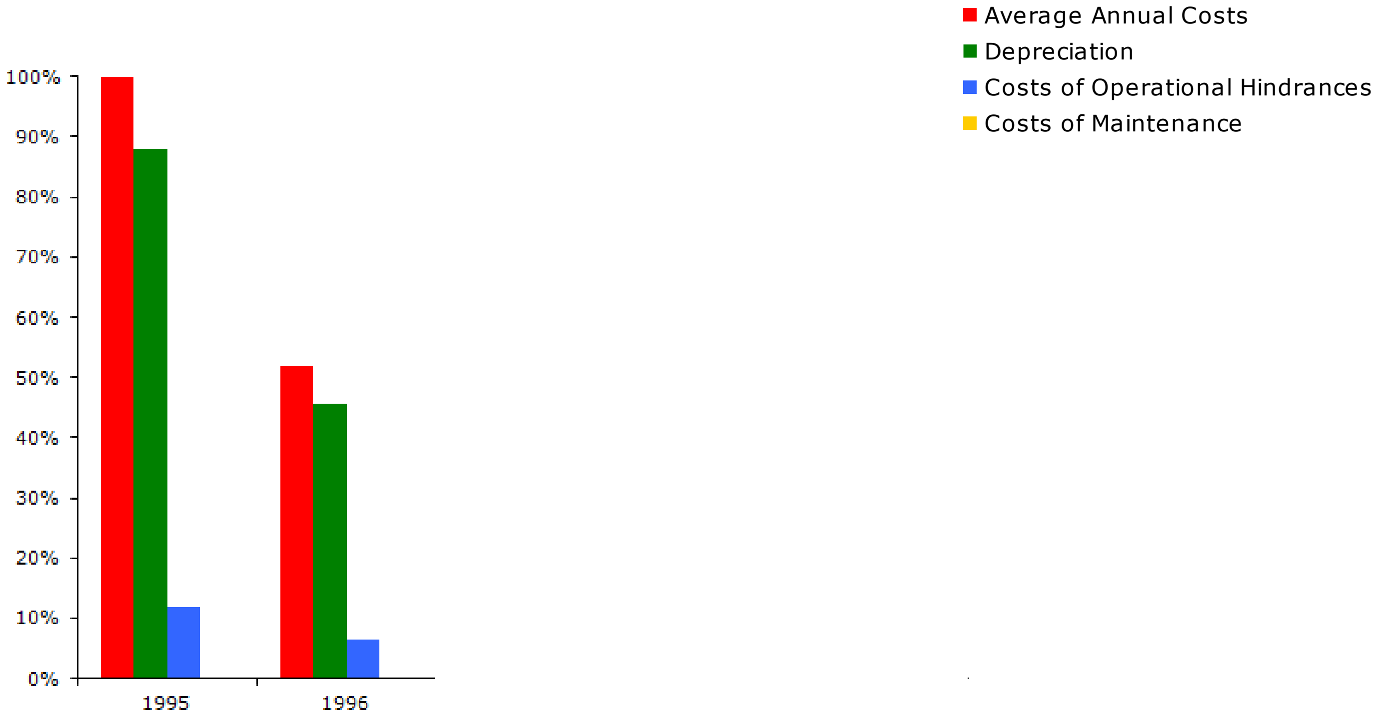


In the first year costs are already about 50% (statistically, dynamically slightly higher).

In the year 2 annuity is equal to the re-investment costs, of course.

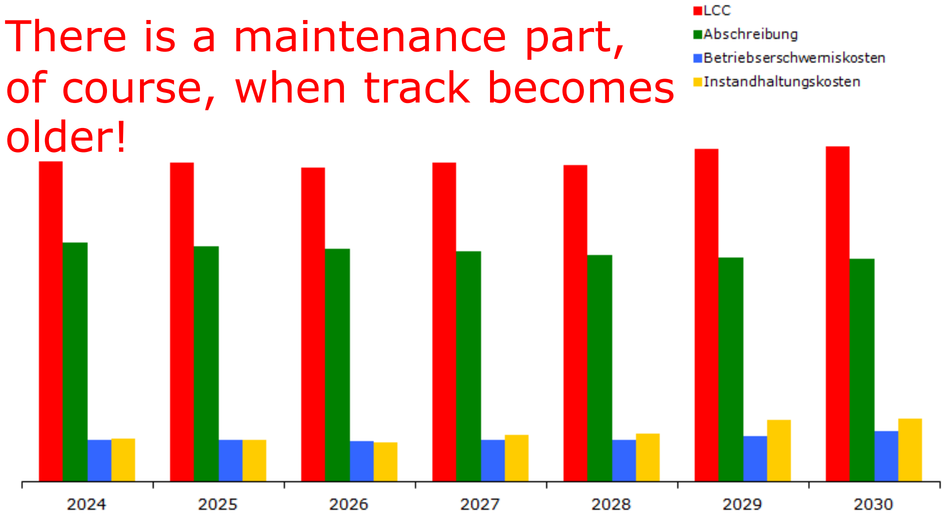
Annuity Monitoring

"Südbahn"	400<R<600	zweigleisig							
GesBT/Tag, Gleis	Profil	Güte	Unterbau		Schwelle				
42.189	60E1	260	gut		Beton				
Instandhaltungsarbeit	ND in Jahren	2,0	1995	1996	1997	1998	1999	2000	2001
Re-Investition (SUZ/AHM)		1,0	1						
Stopfen	alle x Jahre	1,0		1				1	
Schleifen	Anzahl in ND	1,0	1					1	
Schienenwechsel	Anzahl in ND	0,0							
Zwischenlagenwechsel	Anzahl in ND	0,0							
Mängelbehebung	Anzahl in ND	-			1			1,2	

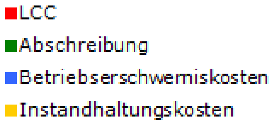


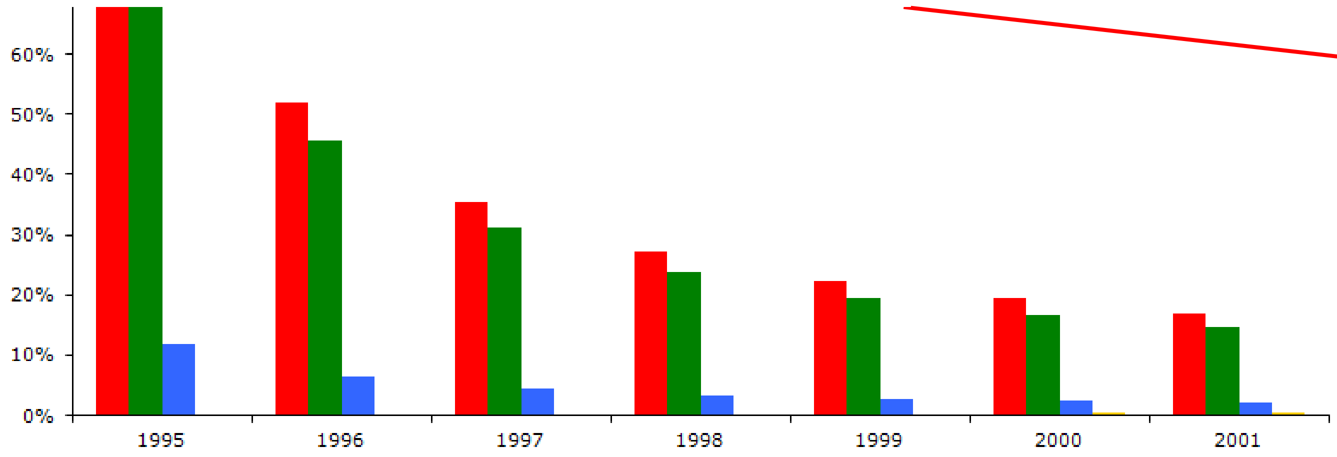
Annuity Monitoring

There is a maintenance part, of course, when track becomes older!



lle		
n		
1999	2000	2001
	1	
	1	
	1,2	





Under Sleeper Pads – Economic Appraisement

Concrete Sleepers with Under Sleeper Pads (USP) lead to

- Stretched Tamping Cycles, a longer Service Life, reduced Small Maintenance — Engineering
- Higher Investment — Financing

❶

Line Category	Alignment	No of Tracks			
Main Line	straight	double-tracked			
Gross-Tonnage per Day	Rail Profile	Steel Grade	Subsoil	Sleeper	Ballast
15,000 - 30,000	60E1	R260	good	concrete	Granite

Track Work	Service Life	40,0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Re-Laying		1,0	1																			
Levelling-Lining-Tamping	every x years	8,0	1								1								1			
Rail Grinding	amount in service life	1,0																				
Rail Grinding HeadChecks	amount in service life	0,0																				
Rail Exchange	amount in service life	0,0																				
Rail Joint Maintenance	amount in service life	0,0																				
Rail Pad Exchange	amount in service life	0,0																				
Small Maintenance	amount in service life	40,0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	1	1	1	1	1	1	1	1

Track Work	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Re-Laying																				
Levelling-Lining-Tamping					1								1							
Rail Grinding					1															
Rail Grinding HeadChecks																				
Rail Exchange																				
Rail Joint Maintenance																				
Rail Pad Exchange																				
Small Maintenance	1	1	1	1	1	1	1	1	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5

Concrete Sleepers

❷

Line Category	Alignment	No of Tracks			
Main Line	straight	double-tracked			
Gross-Tonnage per Day	Rail Profile	Steel Grade	Subsoil	Sleeper	Ballast
15,000 - 30,000	60E1	R260	good	concrete USP	Granite

Track Work	Service Life	50,0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Re-Laying		1,0	1																								
Levelling-Lining-Tampin	every x years	16,7	1																		1						
Rail Grinding	amount in service life	2,0																			1						
Rail Grinding HeadChec	amount in service life	0,0																									
Rail Exchange	amount in service life	0,0																									
Rail Joint Maintenance	amount in service life	0,0																									
Rail Pad Exchange	amount in service life	0,0																									
Small Maintenance	amount in service life	50,0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	1	1	1	1	1	1	1	1

Track Work	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Re-Laying																									
Levelling-Lining-Tampin												1													
Rail Grinding												1													
Rail Grinding HeadChec																									
Rail Exchange																									
Rail Joint Maintenance																									
Rail Pad Exchange																									
Small Maintenance	1	1	1	1	1	1	1	1	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5

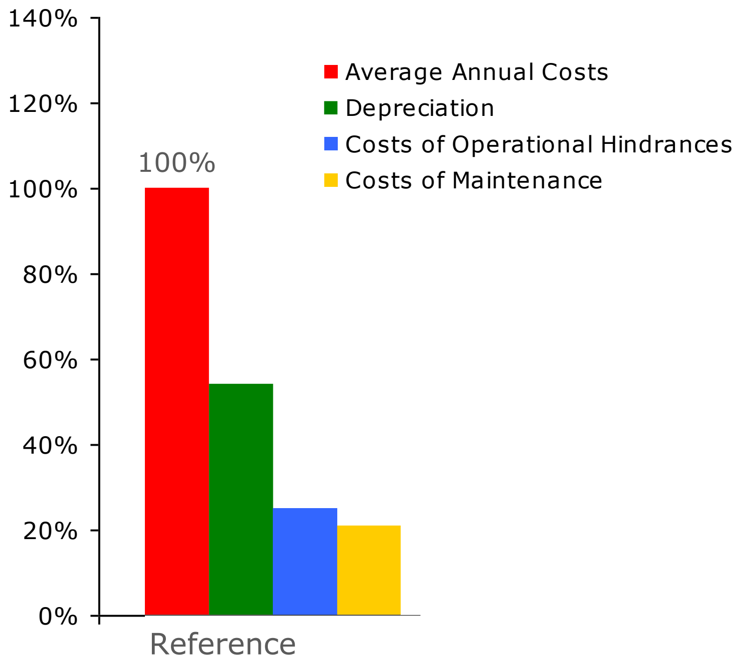
Concrete Sleepers with USPs

ⓘ More Investment Money → this is not for free!

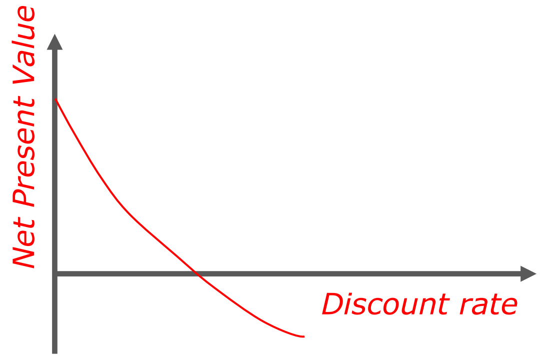
Dynamic Economic Appraisement using an Interest Rate i_{calc}!

Dynamic Evaluation guarantees a) considering the higher investment costs and b) the Uncertainties of future Maintenance / the Service Life Prolongation

Under Sleeper Pads – Economic Appraisement | Result

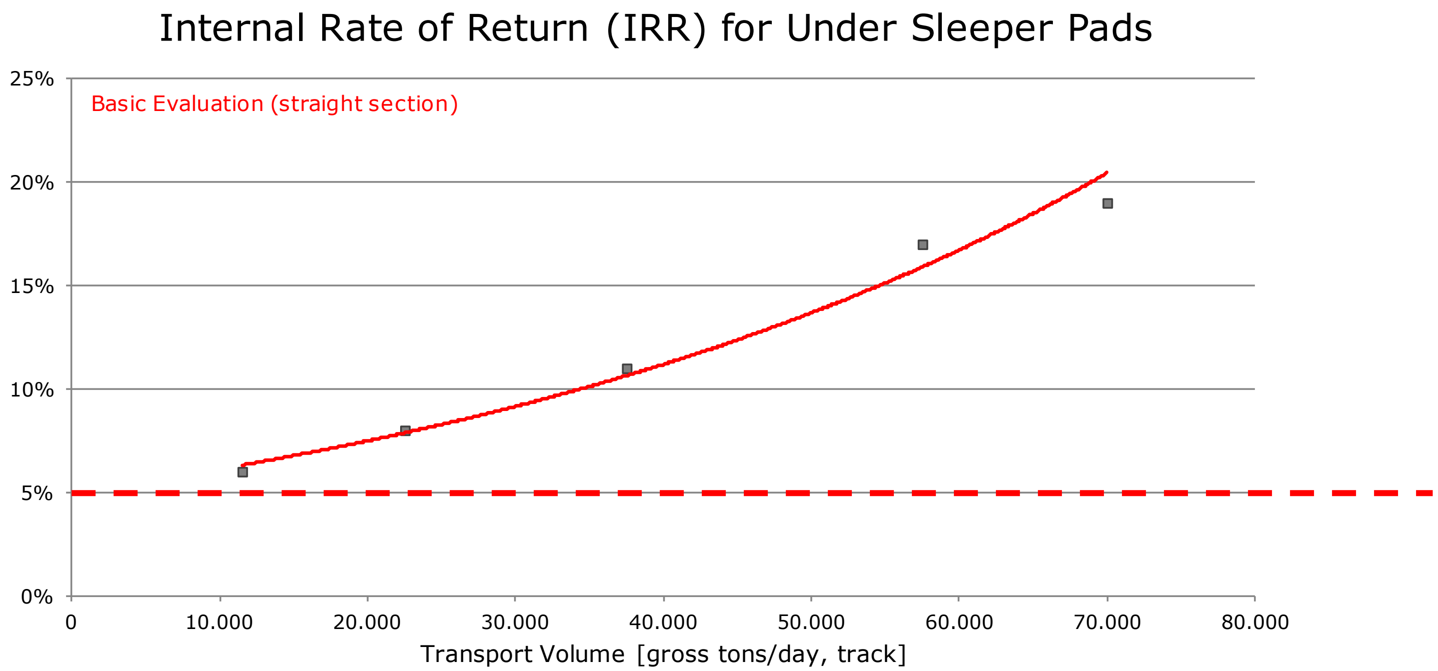


Calculated without interest rate



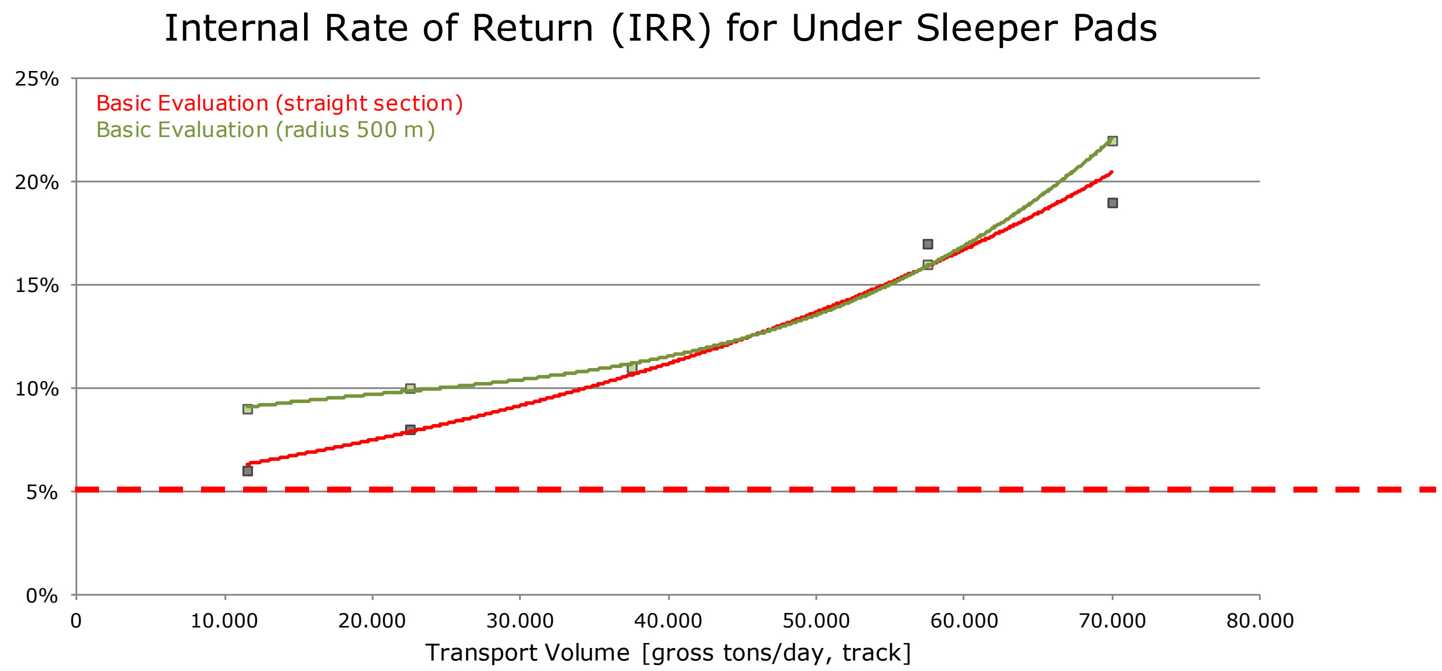
*IRR up to **20%** for high loaded Sections*

Under Sleeper Pads – Economic Appraisement | Result – varying Transport Volume



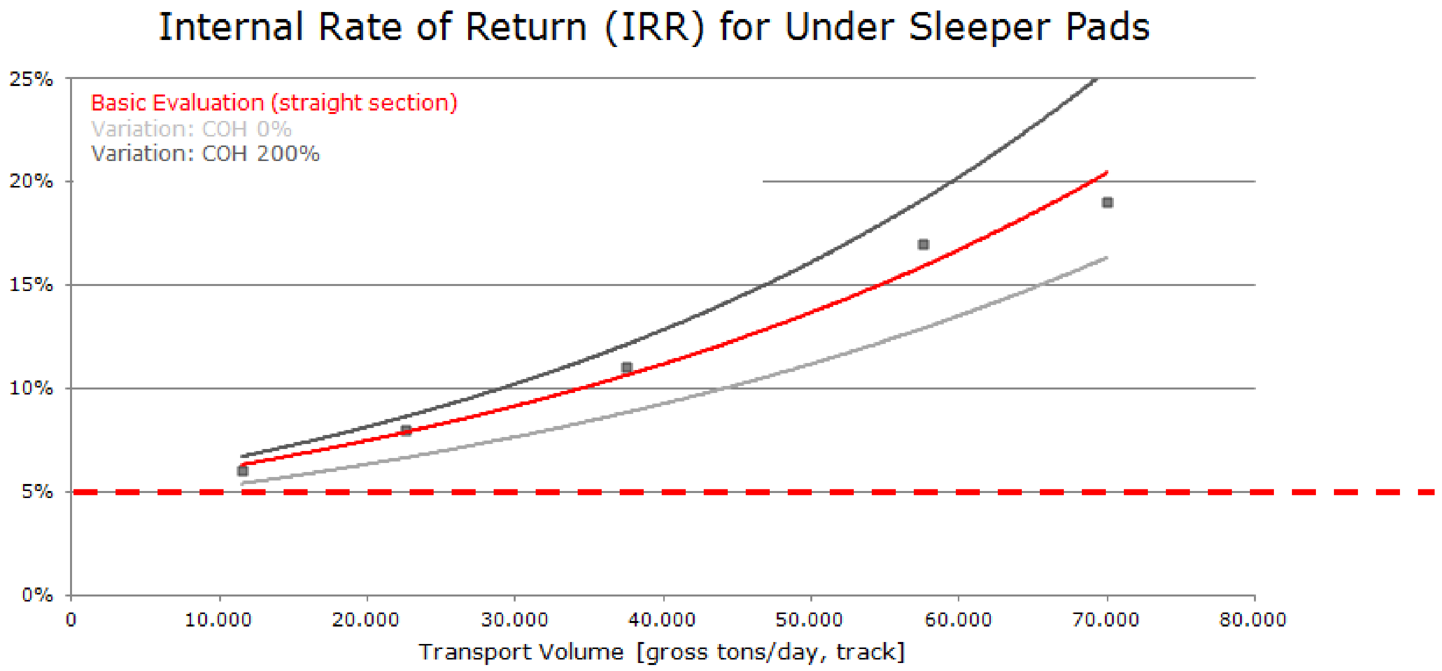
Assuming a required internal rate of return of 5% (real) USP can be proposed independently from the transport volume. However, the higher the transport volume, the higher the benefits.

Under Sleeper Pads – Economic Appraisement | Result – varying Track Radius



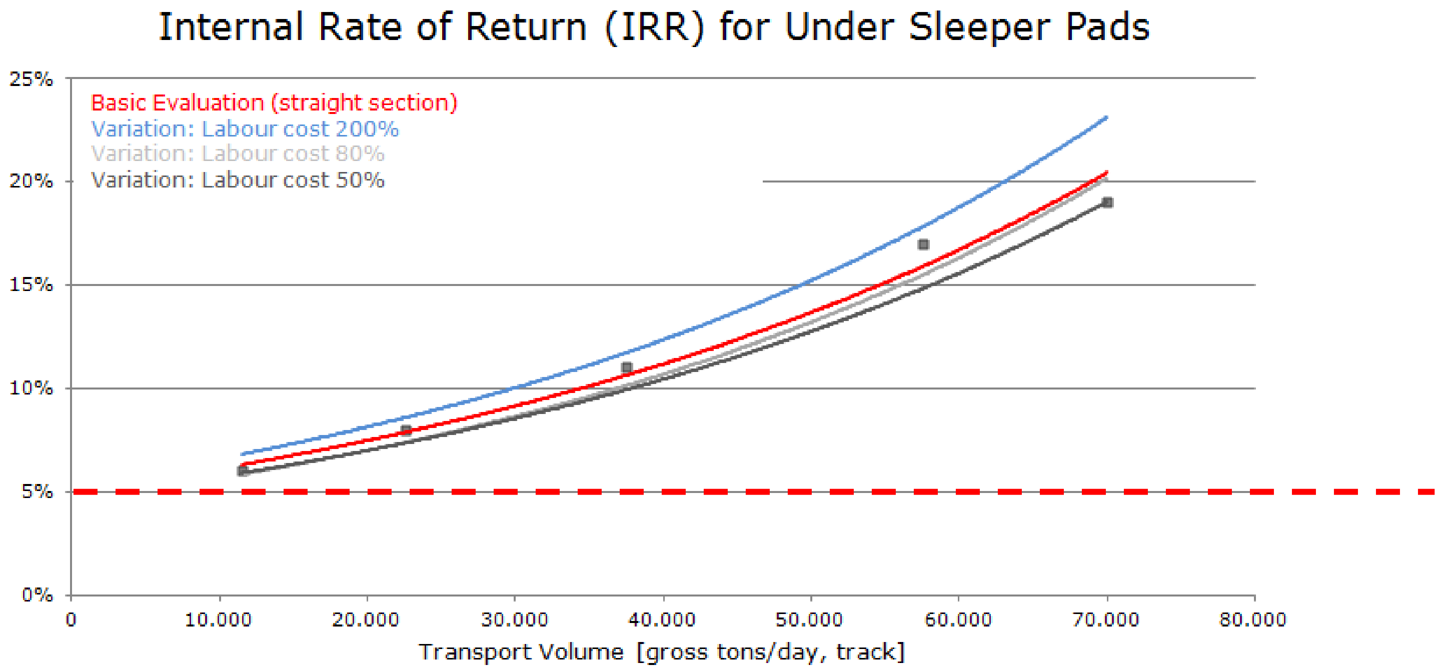
In general the benefits of USP are higher in radii (the smaller the radii the higher the benefits) as radii face in general higher maintenance demands.

Under Sleeper Pads – Economic Appraisement | Result – Sensitivity Costs of Non-Availability



The costs of operational hindrances (COH) influence the results, as reduced maintenance and longer service lives reduce the average annual track closure. However, COH are not a decisive factor for defining the fields of application for USP.

Under Sleeper Pads – Economic Appraisement | Result – Sensitivity Maintenance Cost

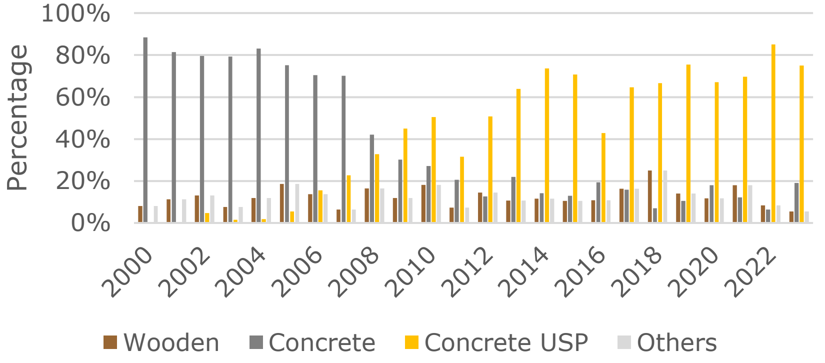


The variation of labour costs show very little impact on the benefits of USP, though the range of variation is rather high (half to double labour costs compared to base case).

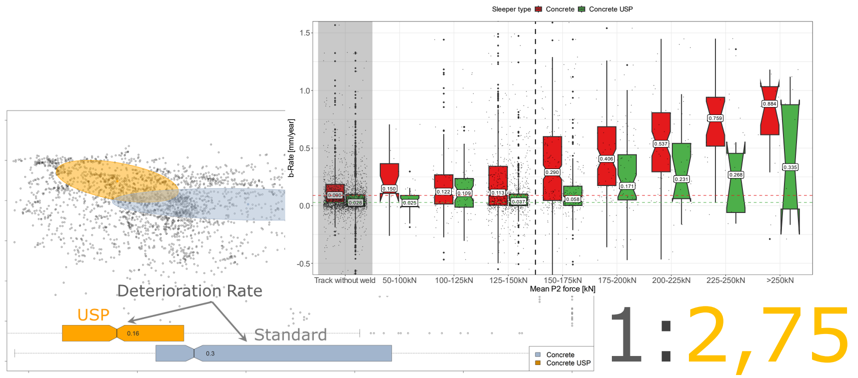
Summary

Summary

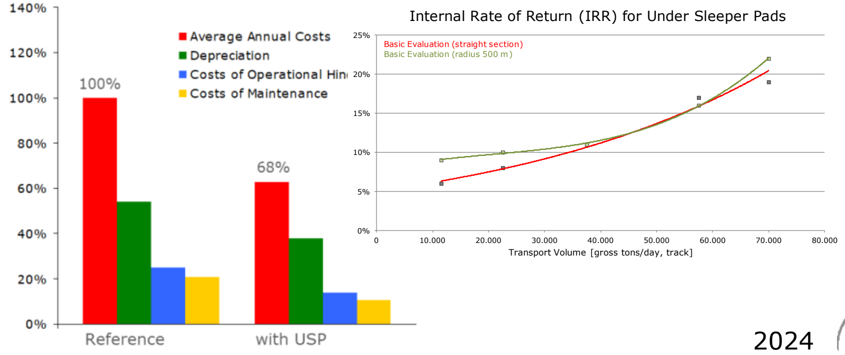
- In Austria, concrete sleepers with under sleeper pads are a success story. Renewals (of main lines) are mostly realised with USPs.



- Several evaluations show the superior performance of USP. Tamping intervals are at least doubled and service life is extended by using USPs.



- While the initial investment is higher for USPs, the improved quality behaviour leads to significant savings in the medium and long term.



Thanks for today!

Questions?

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View into Southern Tube of Koralm-Tunnel (Western Portal minus ~8 km) Direction East, 03. October 2021