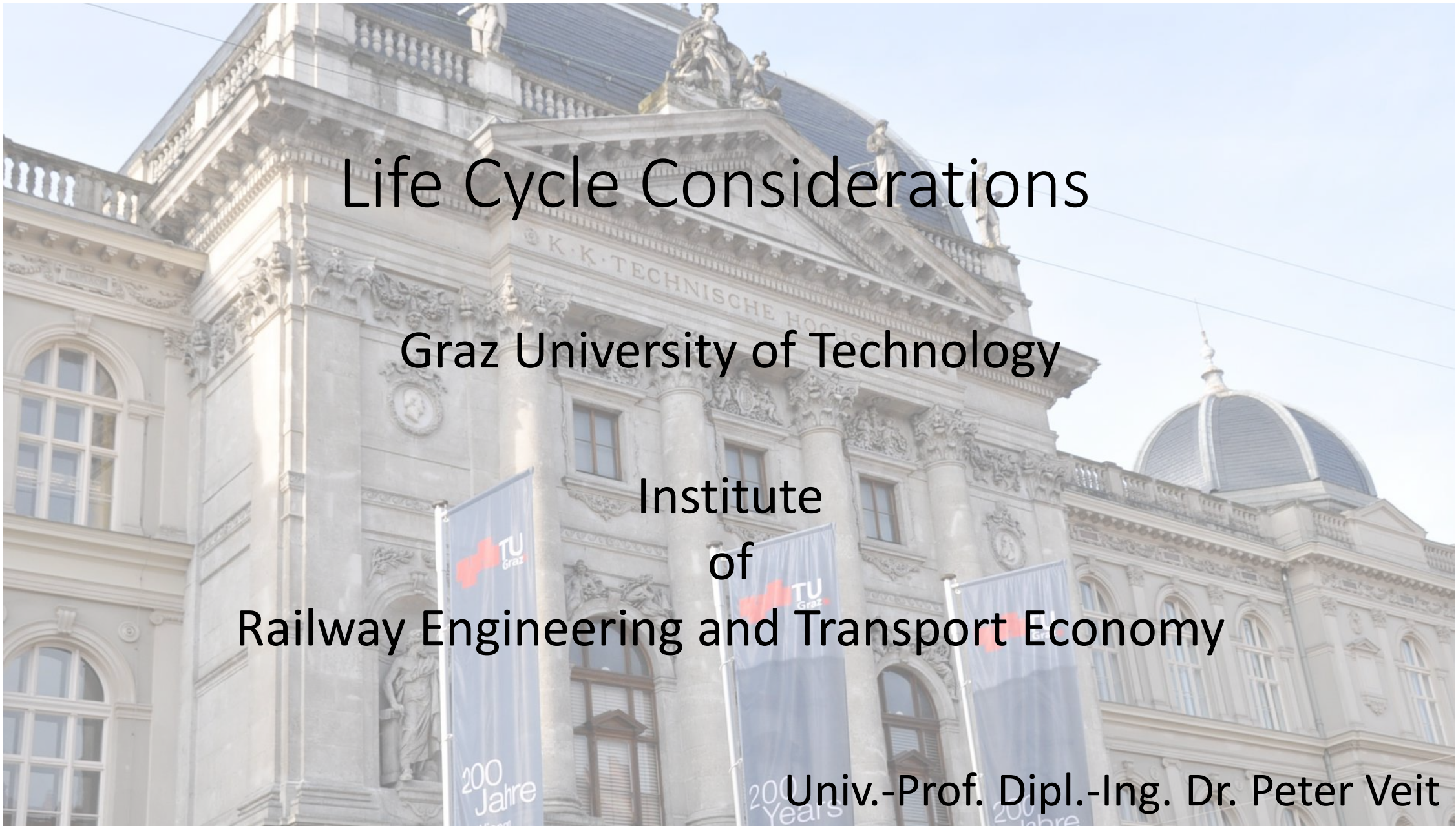

Life Cycle Considerations

Graz University of Technology

Institute
of
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Univ.-Prof. Dipl.-Ing. Dr. Peter Veit

RRB20
RAILWAY ROADBED & BALLAST
SYMPOSIUM

www.ebw.tugraz.at

Challenges

solution: SUSTAINABILITY

technical AND economical

LCM

quality behavior — life cycle costing (LCC)

PREDICTION

Track Quality Behavior – Experience based

A good track behaves well,
a poor one deteriorates faster.

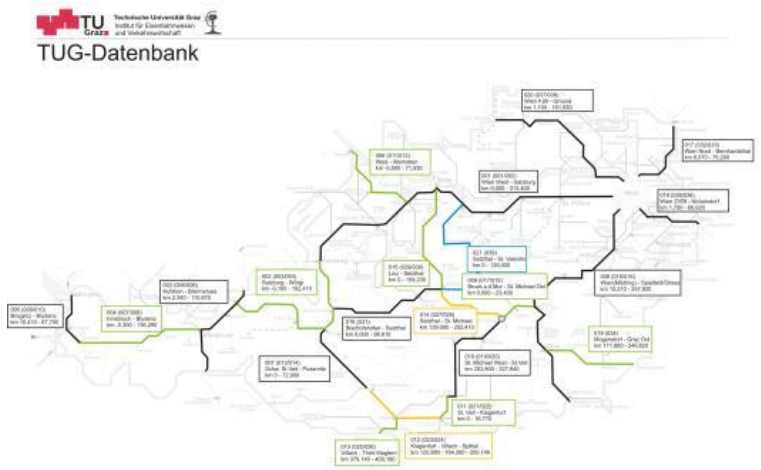
degradation depends on present quality level

quality behavior of track

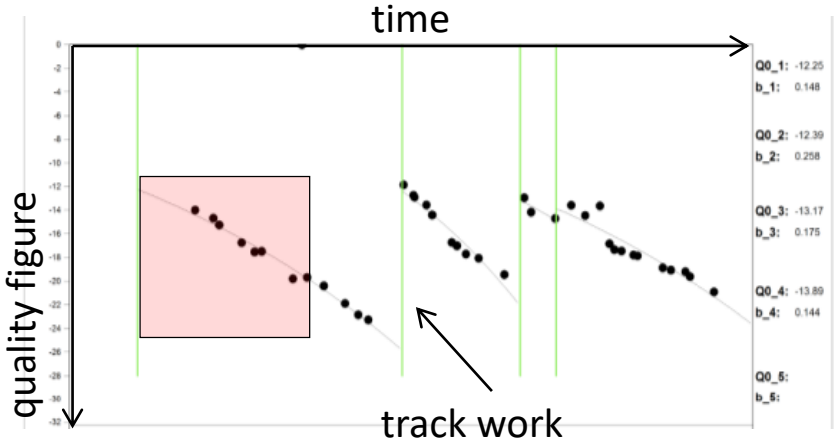
$$Q(t) = Q_0 \times e^{bt}$$

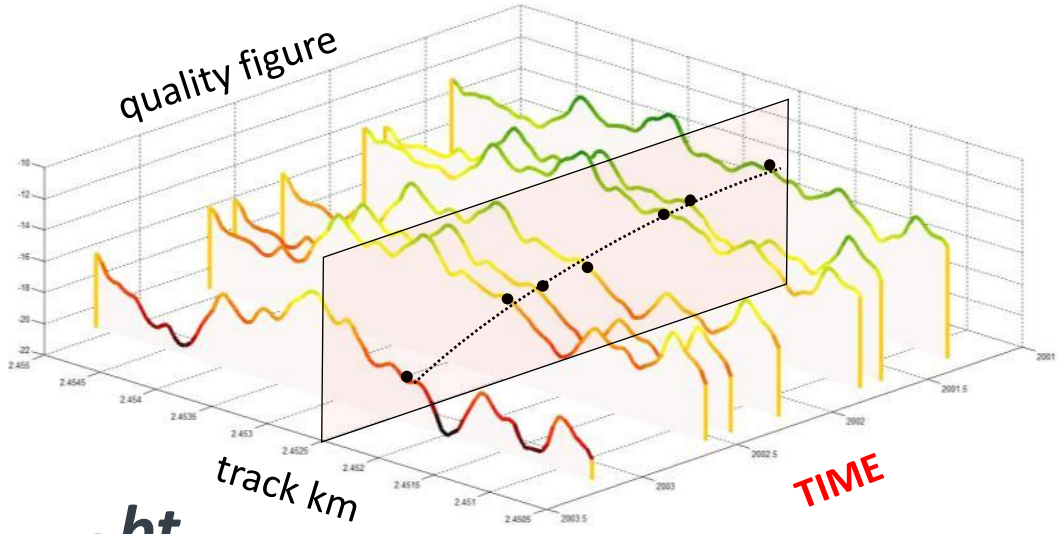
investment + maintenance = **LCC**

Track Quality Behavior – Data based



- data of 4,500 km of main track: type and age of track and its components, recording car data, maintenance data, transport volume, alignment
- time sequences of data since 2001





$$Q(t) = Q_0 \times e^{bt}$$

Track Quality Behavior

$$Q(t) = Q_0 \times e^{bt}$$

Investment + maintenance

Neglected maintenance devaluates every investment!

Investment delivers initial quality which is a kind of potential for service life, but not service life itself.
Maintenance transforms this initial quality into service life.

For optimizing predictive maintenance is required.

Parameters

transport volume [gross-tonnes/day, track]	track [number]	rail profile	rail steel grade	tie	Ballast [LA]	radius [m]	rails [ ]	subsoil condition
> 70,000	1	60E1	R400HT	concrete	< 16	> 3,000 m	CWT	good
45,000 - 70,000	2	54E2	R350HT	concrete USP	16 – 25	1,000 m - 3,000 m	jointed	weak
30,000 - 45,000	2+2	49E1	R260	wooden	> 25	600 m - 1,000 m		poor
15,000 - 30,000			R200	HDS		400 m - 600 m		bad
8,000 - 15,000						250 m - 400 m		
2,000 - 8,000						< 250 m		
< 2,000								

Standard Element

A Standard Element is the description of track facing a certain mix of parameters in depicting the necessary track work over the entire service life.

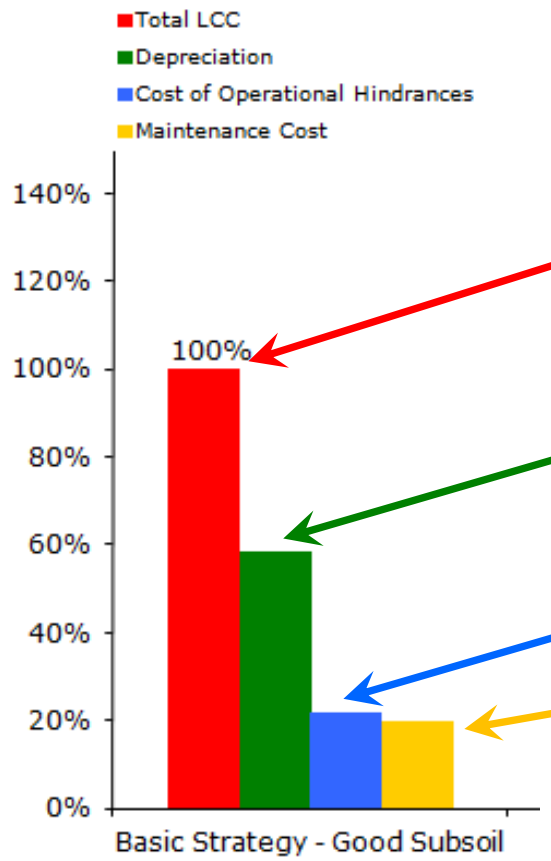
Characteristics of the Standard Element

Double Track Section	Rail Profile			Steel Grade			Tie			Ballast			Subsoil			GBT/Day,Track			Service Life																			
CWT	60E1			R260			Concrete			Granite			Good			15,000 - 30,000			35 years																					
Track Work	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	25	26	27	28	29	30	31	32	33	34	35
Renewal	1																																			
Levelling-Lining-Tamping	1						1						1						1						1						1					
Rail Grinding	1						1												1												1					
Rail Exchange																																				
Sleeper Exchange																																				
Ballast Cleaning																																				
Joint Maintenance																																				
Rail Pad Exchange																																				
Spot Repair	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	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

Planned Maintenance

Small Maintenance (reactive)

Composition of Life Cycle Costs



Annual Life Cycle Costs

Depreciation

Costs Imposed on Operators

Maintenance costs

What ever doing: Keep service life high!

Cost Driver

1. Initial Track Quality precondition: subsoil quality and functionality of drainage
2. Switch Density
3. Ballast Quality
4. Radii
5. Cost of Operational Hindrances
6. Length of Track Work Section
7. Traffic Density
8. Quality of Rolling Stock
9. and of course high speed, mixed traffic, and axle load

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Influence of Sub-Soil

good concrete

400<R<600	zweigleisig			
GesBT/Tag, Gleis	Profil	Güte	Unterbau	Schwelle
15'000-30'000	54E2	R350HT	A	Beton

Gleisarbeit	ND in Jahren	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	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
Erneuerung (Totalumbau)		1,0	1																																																	
Schotterbettreinigung	Anzahl in ND	0,0																																																		
Stopfen	Anzahl in ND	5,0	1										1									1									1									1								1				
Schienenbehandlung	Anzahl in ND	5,0	1										1									1									1									1								1				
Aussenschienenwechsel	Anzahl in ND	1,0																													1																					
Aussen-&Innenschienenwechsel	Anzahl in ND	0,0																																																		
Zwischenlagenwechsel	Anzahl in ND	0,0																																																		
Mängelbehebung	Anzahl in ND	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	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

weak concrete

400<R<600	zweigleisig			
GesBT/Tag, Gleis	Profil	Güte	Unterbau	Schwelle
15'000-30'000	54E2	R350HT	C	Beton

Gleisarbeit	ND in Jahren	25,0	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
Erneuerung (Totalumbau)		1,0	1																								
Schotterbettreinigung	Anzahl in ND	0,0																									
Stopfen	Anzahl in ND	4,0	1										1					1				1			1		
Schienenbehandlung	Anzahl in ND	2,0	1										1									1					
Aussenschienenwechsel	Anzahl in ND	0,0																									
Aussen-&Innenschienenwechsel	Anzahl in ND	0,0																									
Zwischenlagenwechsel	Anzahl in ND	0,0																									
Mängelbehebung	Anzahl in ND	25,0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	1	1	1	1	1	1	1	1	1	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5

Loss of Service Life

good steel

400<R<600	zweigleisig			
GesBT/Tag, Gleis	Profil	Güte	Unterbau	Schwelle
15'000-30'000	54E2	R350HT	A	Stahl

Gleisarbeit	ND in Jahren	40,0	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	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Erneuerung (Totalumbau)		1,0	1																																							
Schotterbettreinigung	Anzahl in ND	0,0																																								
Stopfen	Anzahl in ND	6,0	1						1						1						1						1						1					1				
Schienenbehandlung	Anzahl in ND	6,0	1						1						1						1						1						1					1				
Aussenschienenwechsel	Anzahl in ND	1,0																									1															
Aussen-&Innenschienenwechsel	Anzahl in ND	0,0																																								
Zwischenlagenwechsel	Anzahl in ND	0,0																																								
Mängelbehebung	Anzahl in ND	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	0,5	0,5	1	1	1	1	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

weak steel

400<R<600	zweigleisig			
GesBT/Tag, Gleis	Profil	Güte	Unterbau	Schwelle
15'000-30'000	54E2	R350HT	C	Stahl

Gleisarbeit	ND in Jahren	30,0	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	25	26	27	28	29
Erneuerung (Totalumbau)		1,0	1																											
Schotterbettreinigung	Anzahl in ND	0,0																														
Stopfen	Anzahl in ND	10,0	1						1			1			1			1			1			1		1		1		1		1
Schienenbehandlung	Anzahl in ND	5,0	1						1						1						1					1				1		
Aussenschienenwechsel	Anzahl in ND	1,0																								1						
Aussen-&Innenschienenwechsel	Anzahl in ND	0,0																														
Zwischenlagenwechsel	Anzahl in ND	0,0																														
Mängelbehebung	Anzahl in ND	30,0	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	1	1	1	1	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5

Loss of Service Life

good wooden

400<R<600	zweigleisig			
GesBT/Tag, Gleis	Profil	Güte	Unterbau	Schwelle
15'000-30'000	54E2	R350HT	A	Holz

Gleisarbeit	ND in Jahren	29,0	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	25	26	27	28
Erneuerung (Totalumbau)		1,0	1																											
Schotterbettreinigung	Anzahl in ND	0,0																													
Stopfen	Anzahl in ND	4,0	1						1						1						1						1				
Schienenbehandlung	Anzahl in ND	4,	1						1						1						1						1				
Aussenschienenwechsel	Anzahl in ND	0,																													
Aussen-&Innenschienenwechsel	Anzahl in ND	0,																													
Zwischenlagenwechsel	Anzahl in ND	0,0																													
Mängelbehebung	Anzahl in ND	29,0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5

weak wooden

400<R<600	zweigleisig			
GesBT/Tag, Gleis	Profil	Güte	Unterbau	Schwelle
15'000-30'000	54E2	R350HT	C	Holz

Gleisarbeit	ND in Jahren	22,0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Erneuerung (Totalumbau)		1,0	1																					
Schotterbettreinigung	Anzahl in ND	0,0																						
Stopfen	Anzahl in ND	[illegible]	1						1			1			1			1			1			1
Schienenbehandlung	Anzahl in ND	3,	1						1						1						1			
Aussenschienenwechsel	Anzahl in ND	0,																						
Aussen-&Innenschienenwechsel	Anzahl in ND	0,0																						
Zwischenlagenwechsel	Anzahl in ND	0,0																						
Mängelbehebung	Anzahl in ND	22,0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,5	1,5	1,5	1,5	1,5	1,5	1,5

Loss of Service Life

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Influence of Drainage

If drainage gets a problem, it is always a challenge to set up a proper maintenance ensuring an acceptable service life.

If this combines with weak ballast, it ends up in intensive maintenance and low service lives.

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RAILWAY ROADBED & BALLAST
SYMPOSIUM

good

Schober 2	R>3000																																									
GesBT/Tag, Gleis	Profil	Güte	Unterbau			Schwelle																																				
15.000 - 30.000	60E1	260	gut			Beton																																				
Instandhaltungsarbeit	ND in Jahren	40,0	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	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Neulage		1,0	1																																							
Stopfen	alle x Jahre	8,0	1								1								1								1							1								
Schleifen	Anzahl in ND	1,0																									1															
Schienenwechsel	Anzahl in ND	0,0																																								
Stopfpflege	Anzahl in ND	0,0																																								
Zwischenlagenwechsel	Anzahl in ND	0,0																																								
Mängelbehebung	Anzahl in ND	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	0,5	1	1	1	1	1	1	1	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

poor maintained

	R>600	double track	R>1000																																						
GBT/year,track	rail/sleeper	steel grade	sleeper pad			ballast			subsoil																																	
6.500.000	DE1concretecw	260	no			normal			good																																	
maintenance work	life span	35,0	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	25	26	27	28	29	30	31	32	33	34					
renewal	times/life span	1,0	1																																							
levelling-lining-tamping	every x years	8,0				1				1				1				1				1				1				1				1								
spare pad exchange	times/life span	1,0																				1																				
rail grinding	times/life span	1,0		1																																						
rail exchange	times/life span	0,0																																								
sleeper exchange	times/life span	0,0																																								
ballast cleaning	times/life span	0,5																				0,5																				
subsoil rehabilitation	times/life span	0,0																																								
restressing CWR	times/life span	0,5																				0,5																				
joint maintenance	times/life span	0,0																																								
rail pad exchange	times/life span	1,0																				1																				
spot repair	times/life span	35,0	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	1	1	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					

Loss of Service Life

concrete

not working

Dublin - Cork	R>600	double track																																							
Traffic Volume	Rail Profil	Rail Steel			Sleepers																																					
24.000	540	R260			concrete																																							
Maintenance Work	life span	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30										
total renewal (70% of ballast	times/life span	1,0	1																																							
levelling lining tamping (LLT	every x years	32,0			1		1		1		1		1		1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2									
ballast cleaning	times/life span	0,0																																								
grinding	times/life span	0,0																																								
rail exchange	times/life span	0,0																					0,1					0,1													
sleeper exchange	times/life span	0,0																																								
ballast (40% of ballast	times/life span	1,0											0,5										0,5								0,2										
rail pad exchange	times/life span	0,0																																								
drainage maintenance	times/life span	1,0																					1																			
single sleeper exchange	times/life span	0,0																																								
spot ballast addition	times/life span	0,0																																								
spot tamping	times/life span	0,0																																								
further spot repair	times/life span	0,0																																								
speed reduction	times/life span	0,0																																								

Loss of Service Life

Influence of Ballast Quality

granite

Schober 2	R>3000																																									
GesBT/Tag, Gleis	Profil	Güte	Unterbau			Schwelle																																				
15.000 - 30.000	60E1	260	gut			Beton																																				
Instandhaltungsarbeit	ND in Jahren	40,0	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	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Neulage		1,0	1																																							
Stopfen	alle x Jahre	8,0	1								1								1								1								1							
Schleifen	Anzahl in ND	1,0																									1															
Schleifen HeadChecks	Anzahl in ND	0,0																																								
Schienenwechsel	Anzahl in ND	0,0																																								
Stoßpflege	Anzahl in ND	0,0																																								
Zwischenlagenwechsel	Anzahl in ND	0,0																																								
Mängelbehebung	Anzahl in ND	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	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

limestone

	R>600	double track	R>1000																																		
GBT/year,track	rail/sleeper	steel grade	sleeper pad			ballast			subsoil																												
6.500.000	0E1concreteCW	260	no			normal			good																												
maintenance work	life span	35,0	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	25	26	27	28	29	30	31	32	33	34
renewal	times/life span	1,0	1																																		
levelling-lining-tamping	every x years	8,0				1				1				1				1				1				1				1				1			
spare part exchange	times/life span	1,0																				1															
rail grinding	times/life span	1,0		1																																	
rail exchange	times/life span	0,0																																			
sleeper exchange	times/life span	0,0																																			
ballast cleaning	times/life span	0,5																				0,5															
subsoil rehabilitation	times/life span	0,0																																			
restressing CWR	times/life span	0,5																				0,5															
joint maintenance	times/life span	0,0																																			
rail pad exchange	times/life span	1,0																				1															
spot repair	times/life span	35,0	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	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

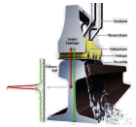
Loss of Service Life

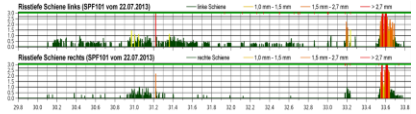
Ballasted track with limestone-ballast shows up to 20 per cent reduction of service life compared to track with granite ballast. The loss of service life for turnouts is minimum 30 per cent.

Normally there is no lack of data but…

Rail

Eddy current
Ultrasonic
Rail profile
→ Grinding/Milling
Rail exchange





[ÖBB NATAS]

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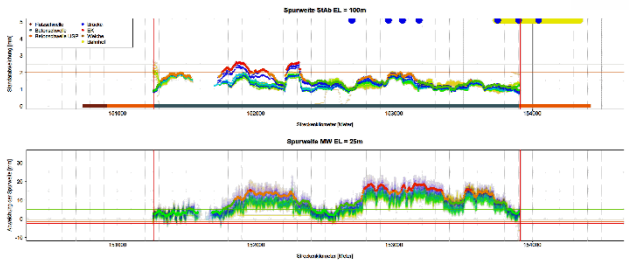
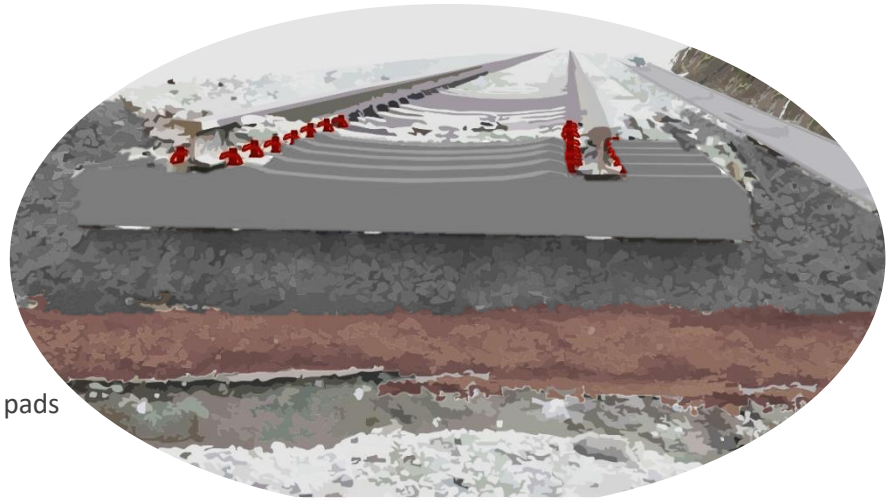
Sleepers/Force Transmission

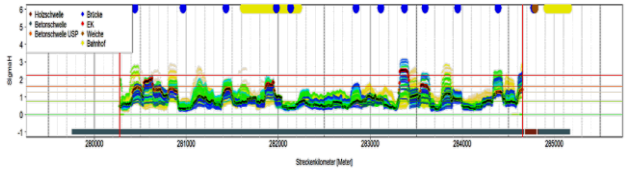
Standard deviation of modified track gauge
→ Exchange of sleepers/rail pads
Screw hole renewal





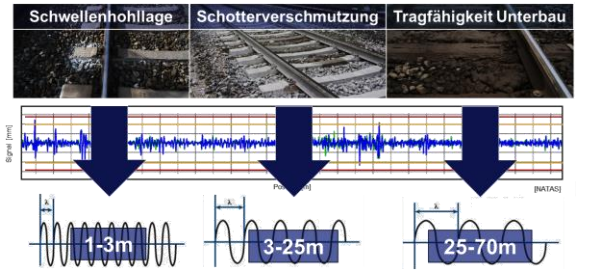
Track quality

Vertical track geometry
Horizontal track geometry
Twist
Cant
→ Single failure tamping
Line tamping



Ballast/Sub-Soil

Fractal analyses of vertical track geometry
→ Ballast cleaning
Undercutting
(Substructure renewal)



… there is a lack of analyzing the data. However, collecting and storing is not enough.

Example: Under Sleepers Pads

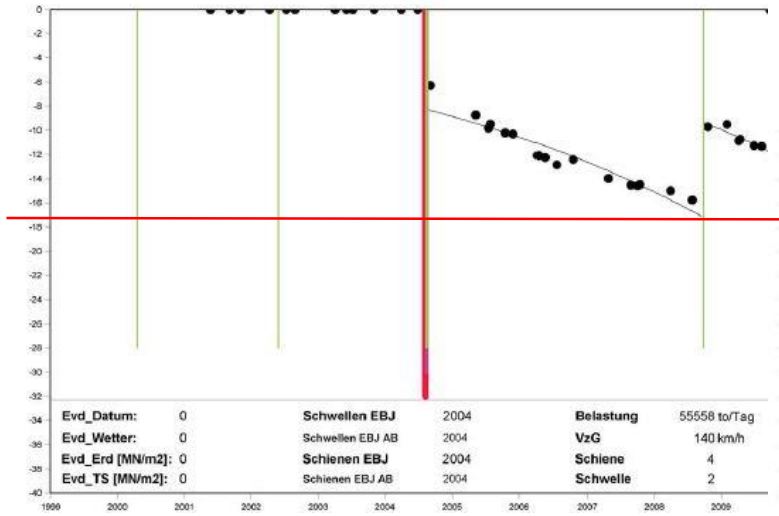
Concrete ties are the best option: best side resistance, lowest investment (Europe), least maintenance demand, longest service life, but high deterioration of ballast.

Tests showed that conventional concrete ties have less than 10 per cent contact area to the ballast bed, even after stabilizing.

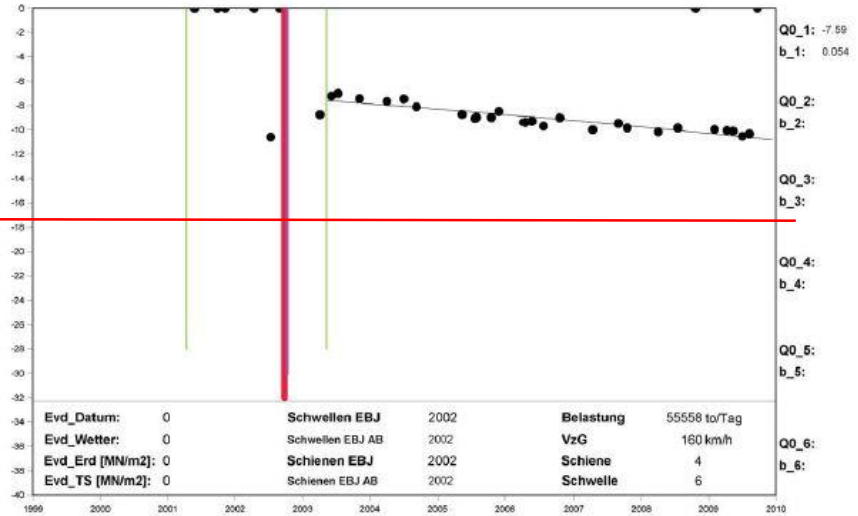
Ties with Elastic Footing (USP)

The polyurethane layer has two main benefits, elasticity and up to 30 per cent contact area, reducing stresses in ballast bed and thus reducing (initial) settlements.

Under Sleeper Pads



Reference: 60E1 rails on conventional concrete ties

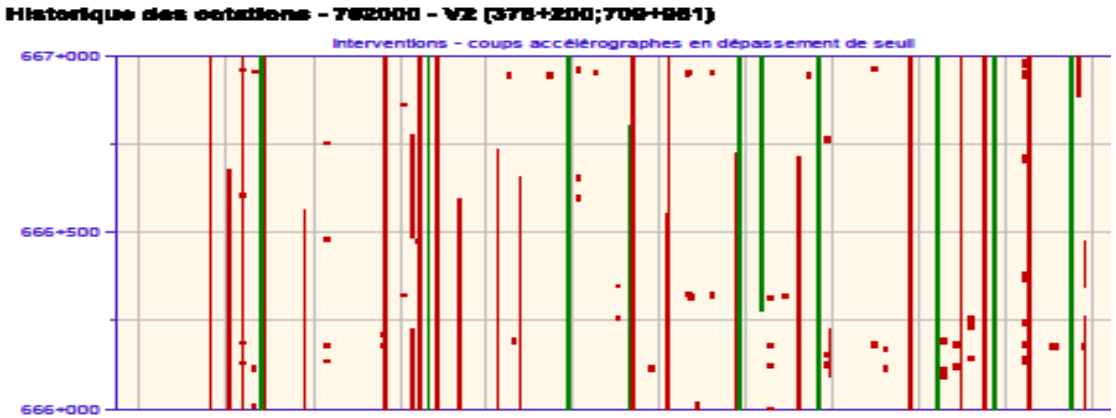


60E1 rails on USP ties

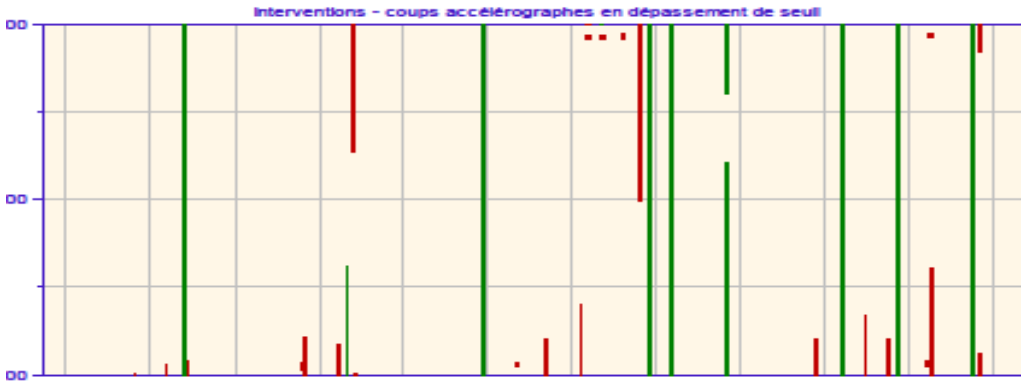
The difference in degradation is huge – delivering completely different behaving of track.

Under Sleeper Pads - SNCF

without elastic footing



with elastic footing



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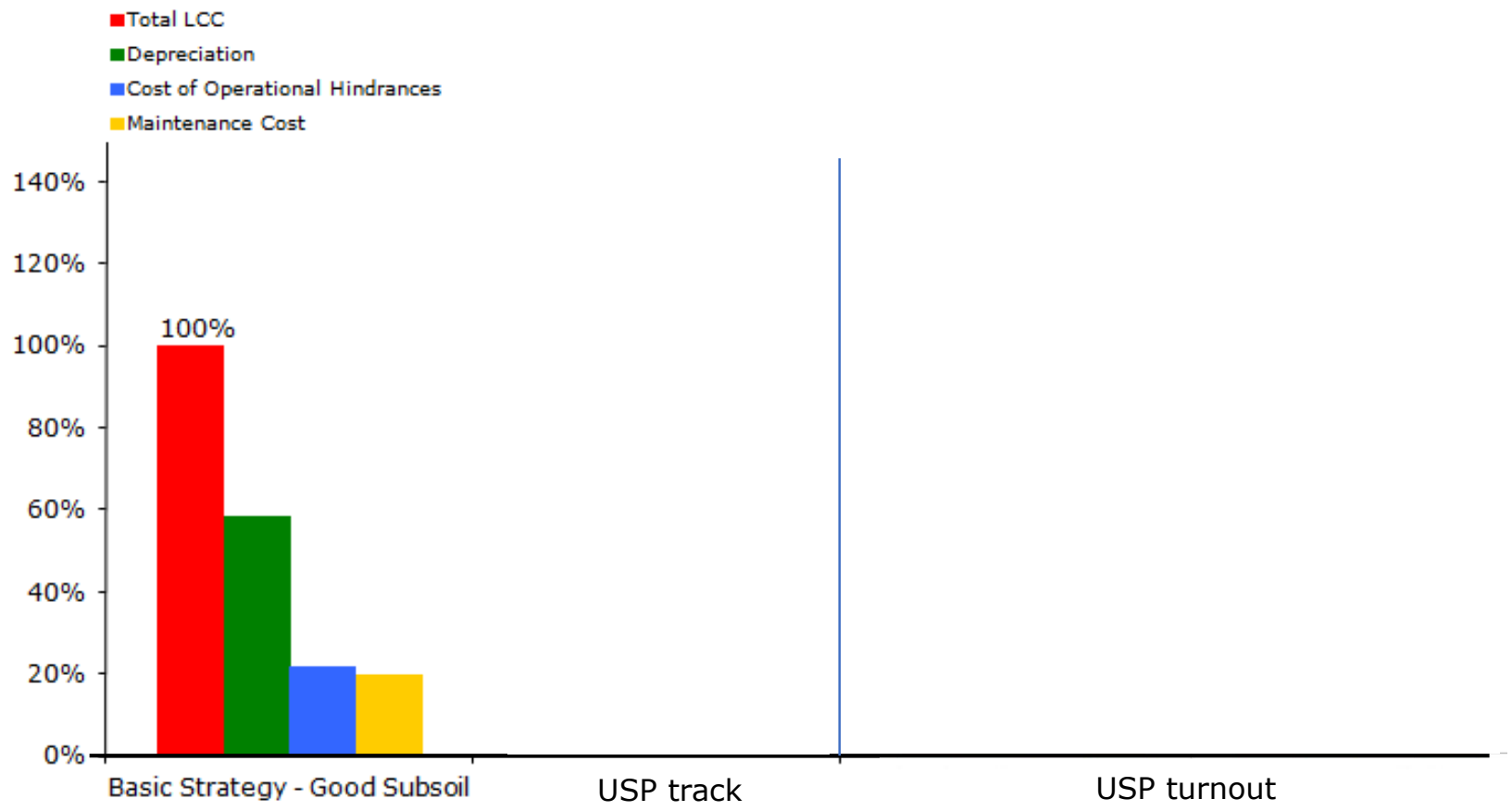
Under Sleeper Pads

Result of economic evaluation track and turnouts



life cycle costs track : turnout ~ 1:11

International Applicability?

It is easy to adopt the parameter sets to the specific situation of a specific railroad network

as there is no parameter called “nationality of track”.

However, if operation and rolling stock is totally different it becomes a little bit tricky…

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Recalculation of Behavior due to Different Operation

Tamping Demand Existing
at an existing Mixed-Traffic Line

every 5 years

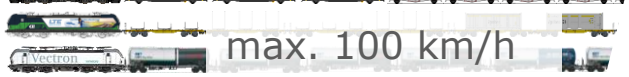
70,000 Loading
Gross-tonnage

$\times \frac{\Sigma P_2^3}{\Sigma P_2^3} =$

Tamping Demand Estimated
for a new High-Speed Line

4 times a year

Loading
Gross-tonnage 195,000

36		max. 230 km/h
14		
24		max. 160 km/h
17		
7		max. 120 km/h
10		
5		
2		max. 100 km/h
2		
33		

ΣP_2^3

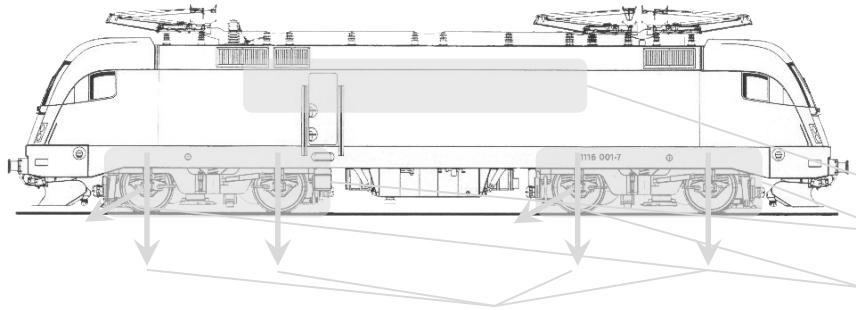
360

ΣP_2^3

1. Extracting the Tamping Cycle of an existing Line
2. Calculated ΣP_2^3 for existing Loading Collective
3. Calculated ΣP_2^3 for existing Loading Collective for the new Line
4. Calculate the Tamping Cycle for the new Line

Swiss Wear Factor

SBB CFF FFS



The Input of the Vehicle

T_{PV} (installed) power density transferred by the contact patch

W_{b_R} frictional energy exerted during wheel/rail contact in curves

$Y_{R=185m}$ lateral force of the leading wheel on the outside of the curve

$P_{2,V}$ dynamic Axle Load (static Axle Load, un-sprung mass, speed)

$$C_V = k1_R \times P_{2,V}^{3} + k2 \times P_{2,V}^{1,2} + k3 \times T_{pv} + k4_R \times W_{b_R} + k5 \times \sqrt{(0.5 \times P_{2,40kmph}^{2} + 0.5 \times Y_{R=185m}^{2})}$$

Wear/Damage of Track

Track Geometry Failures
Ballast Deterioration

Rail Surface Failures straight Track
Rail Surface Failures curved Track (RCF)
Rail Wear curved Track

Turnout Component Wear

Track Cost

Tamping and Ballast Cleaning

Rail Grinding (straight)

Rail Grinding (curve)

Rail Exchange (curve)

Turnout Component Exchange

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SUMMARY

Summary

Thank You! – Questions?

We should have a closer look to track behaviour.

There is nothing more expensive than short term savings.

There is nothing more economic than high quality.

Sustainable reducing of infrastructure costs requires investing in quality.

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