Graz University of Technology
Institute of Railway Engineering and Transport Economy

Prognosis of Switches

Analogies and Differences to Open Track

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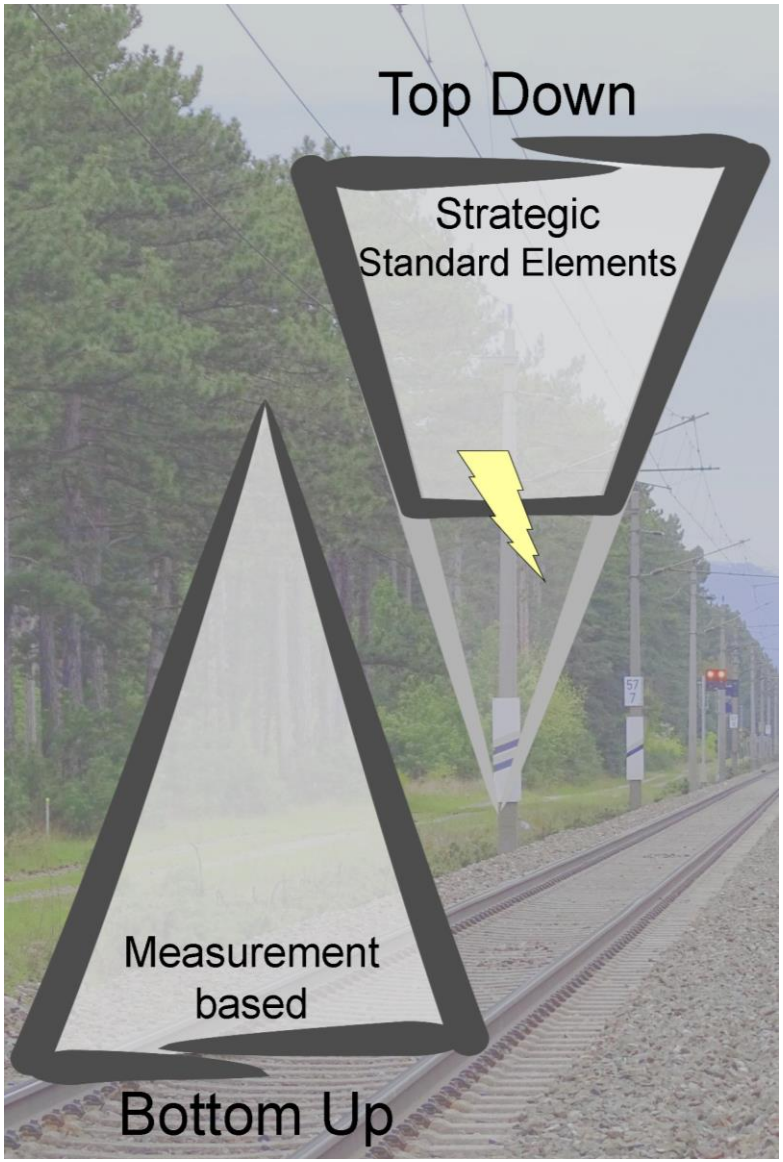
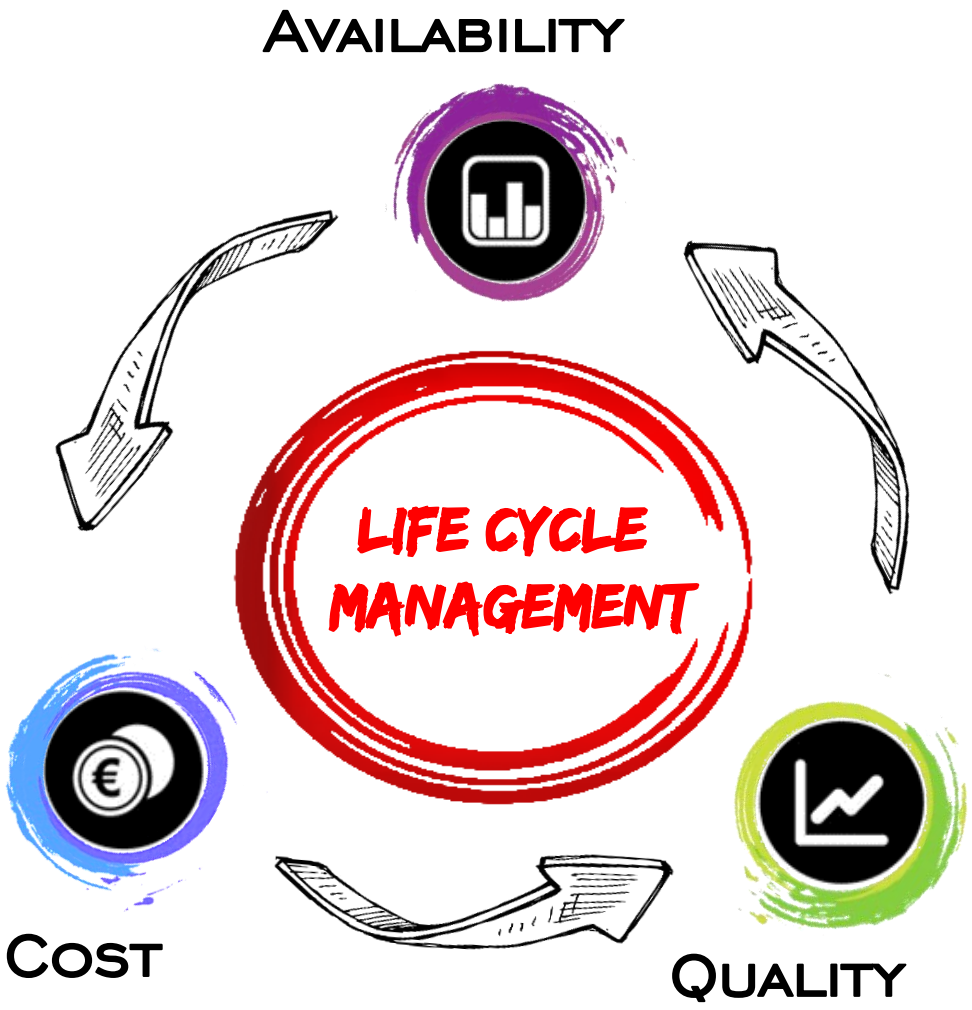

Top Down
Strategic
Standard Elements
Measurement
based
Bottom Up


AVAILABILITY
LIFE CYCLE
MANAGEMENT
COST
QUALITY

Standard Elements Track AND Switches

traffic load [gross tons/day, track]	# of tracks [-]	radius [m]	rail profile [-]	rail steel grade [-]	sleeper [-]	subsoil [-]
8,000 – 15,000	1	≤ 250	49E1	R200	wooden	good
15,000 – 30,000	2	250 < R ≤ 400	54E2	R260	concrete	poor
30,000 – 45,000		400 < R ≤ 600	60E1	R350 HT	concrete w. USP	weak
45,000 – 70,000		600 < R ≤ 1,000				bad
> 70,000		1,000 < R ≤ 3,000				
		R > 3,000				

	400<R<600	zweigleisig																							
GesBT/Tag, Gleis	Profil	Güte	Unterbau		Schwelle																				
>100'000	54E2	R350HT	A		Holz																				
Gleisarbeit	ND in Jahren	23,0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Erneuerung (Totalumbau)		1,0	1																						
Schotterbettreinigung	Anzahl in ND	0,0																							
Stopfen	Anzahl in ND	11,0	1		1		1		1		1		1		1		1		1		1		1		1
Schienenbehandlung	Anzahl in ND	11,0	1		1		1		1		1		1		1		1		1		1		1		1
Aussenschienenwechsel	Anzahl in ND	2,0							1												1				
Aussen-&Innenschienenwechsel	Anzahl in ND	1,0													1										
Zwischenlagenwechsel	Anzahl in ND	0,0																							
Mängelbehebung	Anzahl in ND	23,0	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	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5

Standard Elements Track AND Switches

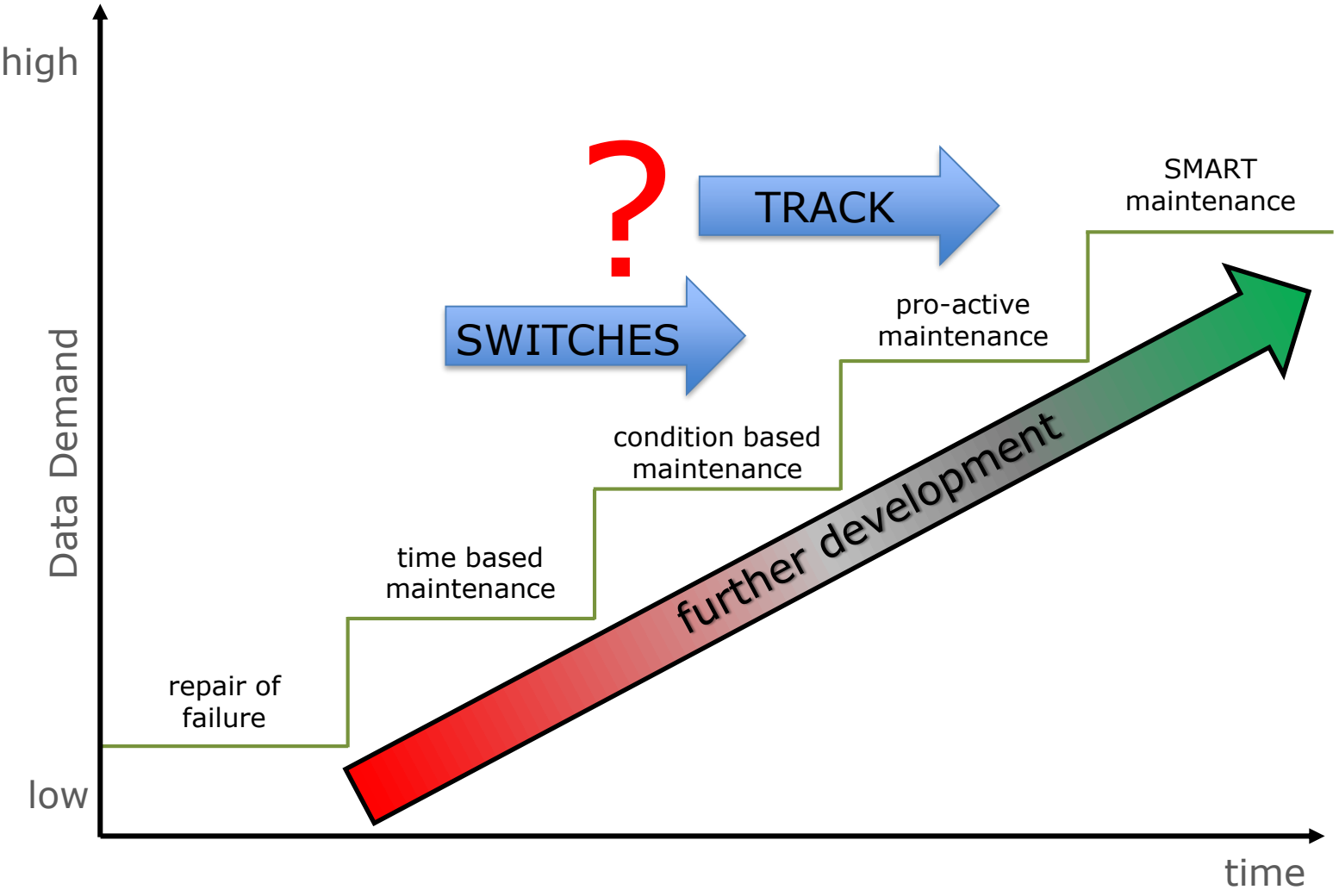
traffic load [gross tons/day, track]	# of tracks [-]	radius [m]	rail profile [-]	rail steel grade [-]	sleeper [-]	subsoil [-]
8,000 – 15,000	1	≤ 250	49E1	R200	wooden	good
15,000 – 30,000	2	250 < R ≤ 400	54E2	R260	concrete	poor
30,000 – 45,000		400 < R ≤ 600	60E1	R350 HT	concrete w. USP	weak
45,000 – 70,000		600 < R ≤ 1,000				bad
> 70,000		1,000 < R ≤ 3,000				
		R > 3,000				

traffic load [gross tons/day, track]	traffic diverted	# of tracks [-]	radius [m]	rail profile [-]	sleeper [-]	subsoil [-]	frog [-]	velocity [km/h]
2,500	10%	1	190	49E1	wooden	good	Mn rigid	< 200
12,500	20%	2	300	54E2	concrete	poor	Mn moving	> 200
18,000	50%		500	60E1	concrete with USP	weak	FVC	
33,000	90%		760			bad		
55,000			1,200					
90,000			1,600 / 2,600					

Standard Elements Track AND Switches

Infrastructure Company	Implementation	Standard Elements Track	Standard Elements Switches
ÖBB	LCC based regulations for Investment and maintenance	1999 basic strategies	2001 basic strategies
ÖBB		2006 detailed component strategies	2006 detailed component strategies
ÖBB		2010 update (cost and RCF)	2013 update (cost and RCF)
SBB	budgeting	2010 components	2010 components
HŽ		2006 components	2006 components
Bane NOR	investment strategies	2008 strategies	-

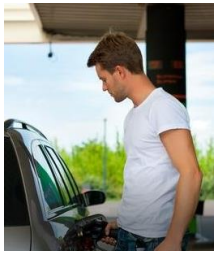
Development of Maintenance



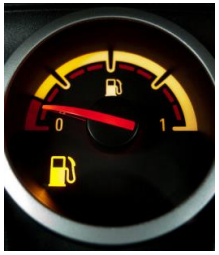
Development of Maintenance

From "repair of failures"
towards
"pro-active maintenance"

fail&fix



do&prevent



monitor&prevent

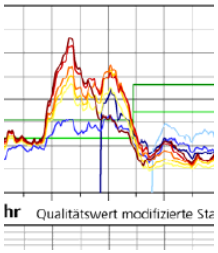
predict&prevent

Example "Head Checks"

fail&fix

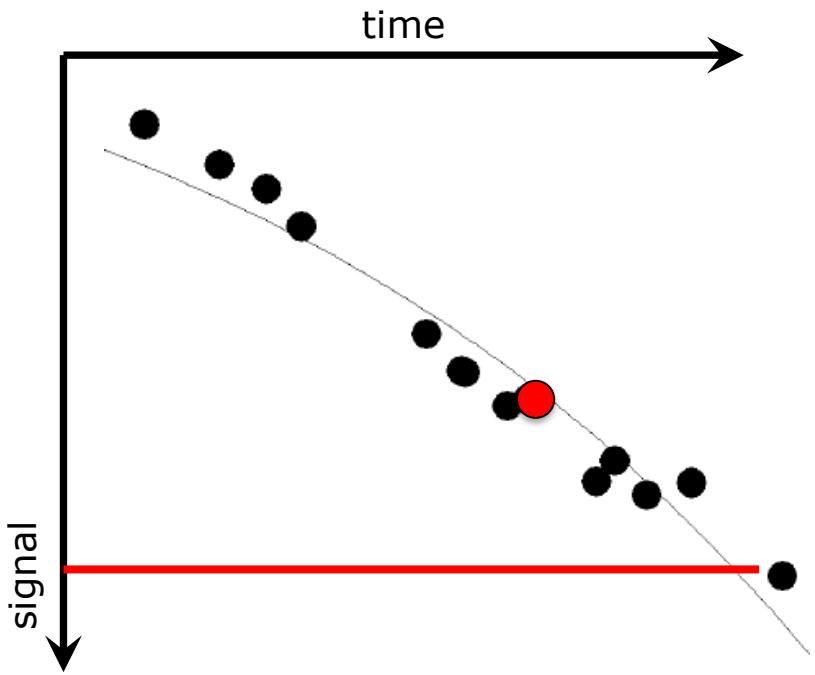
do&prevent

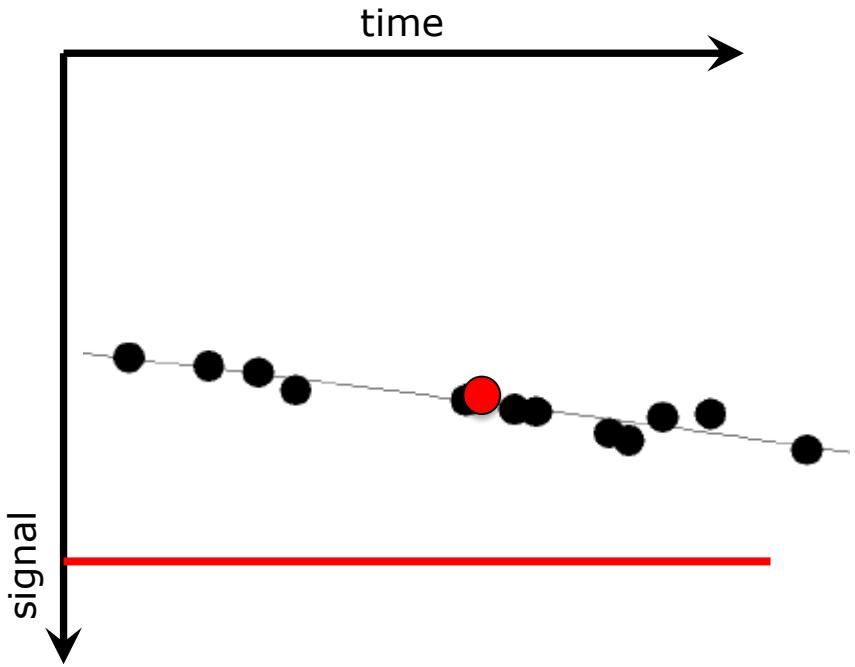
find&fix



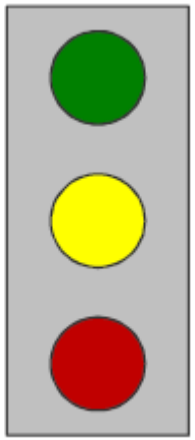
monitor&prevent

number of interventions	**minimum**	**maximum**	low	**optimum**
availability	**minimum**	low	**high**	**maximum**
risk of system fallout	**100%**	**low**	**-**	**-**





predictive maintenance



asset ok

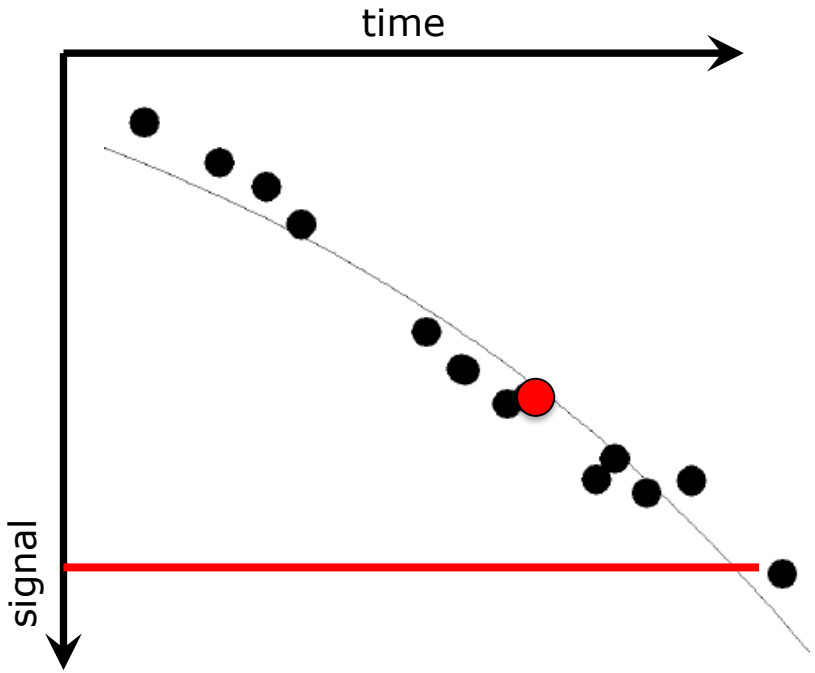
asset conspicuous

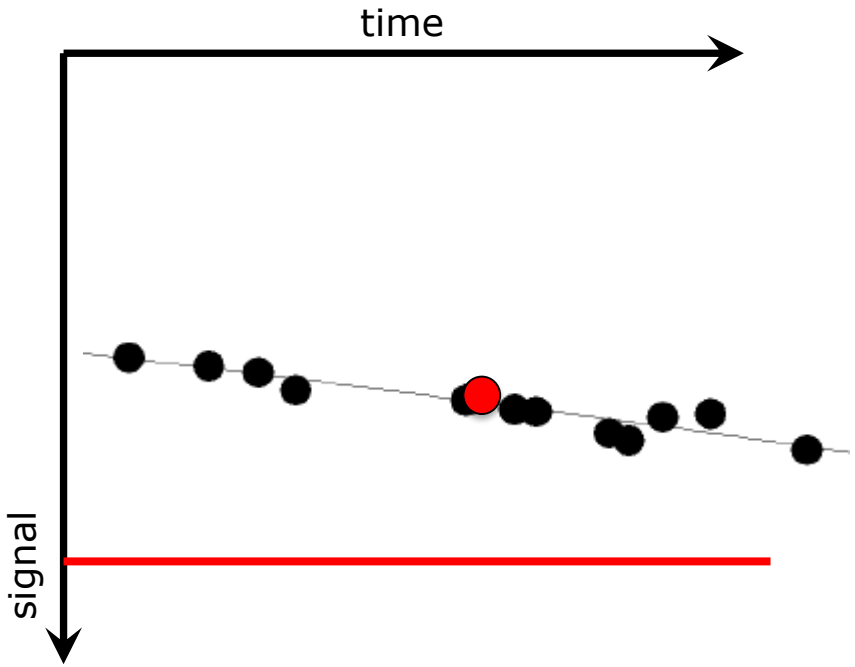
asset break-down

minimum number of interventions

behaviour taken into account

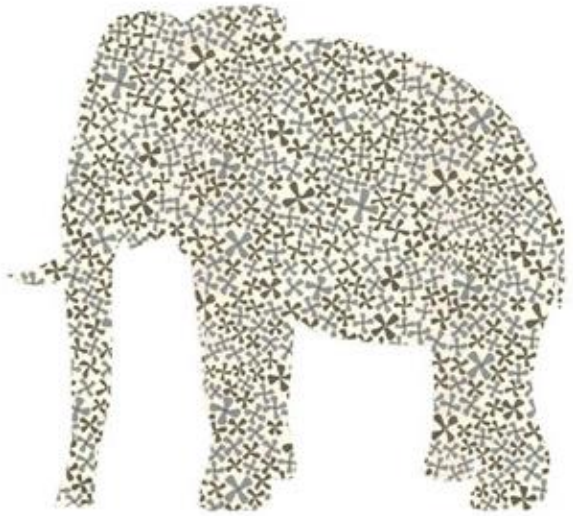
avoided





IT REQUIRES THINKING IN QUALITY BEHAVIOUR OVER TIME INSTEAD OF DEALING WITH SINGLE VALUES ONLY

Reality → Model



Track is patient, not immediately reacting if treated insufficiently.

Switches are patient, not immediately reacting if treated insufficiently.

Track has got a remarkable memory. It remembers insufficient support.

Switches have got a remarkable memory. They remember insufficient support.

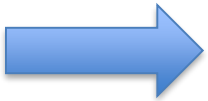
Whenever track reacts, service life is already gone!

Whenever switches react, service life is already gone!

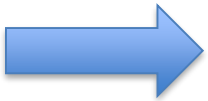
Let's transfer the experiences from track to switches!

Life Cycle Costs – Track versus Switches

load gross-tonnes/day	life cycle cost track	life cycle cost switch
70,000	2.2	2.1
50,000	1.5	1.4
30,000	**1.0**	**1.0**
	LCC relation	
EW 190	**1.0**	12.6
EW 300		11.5
EW 500		10.7
EW 1200		10.0



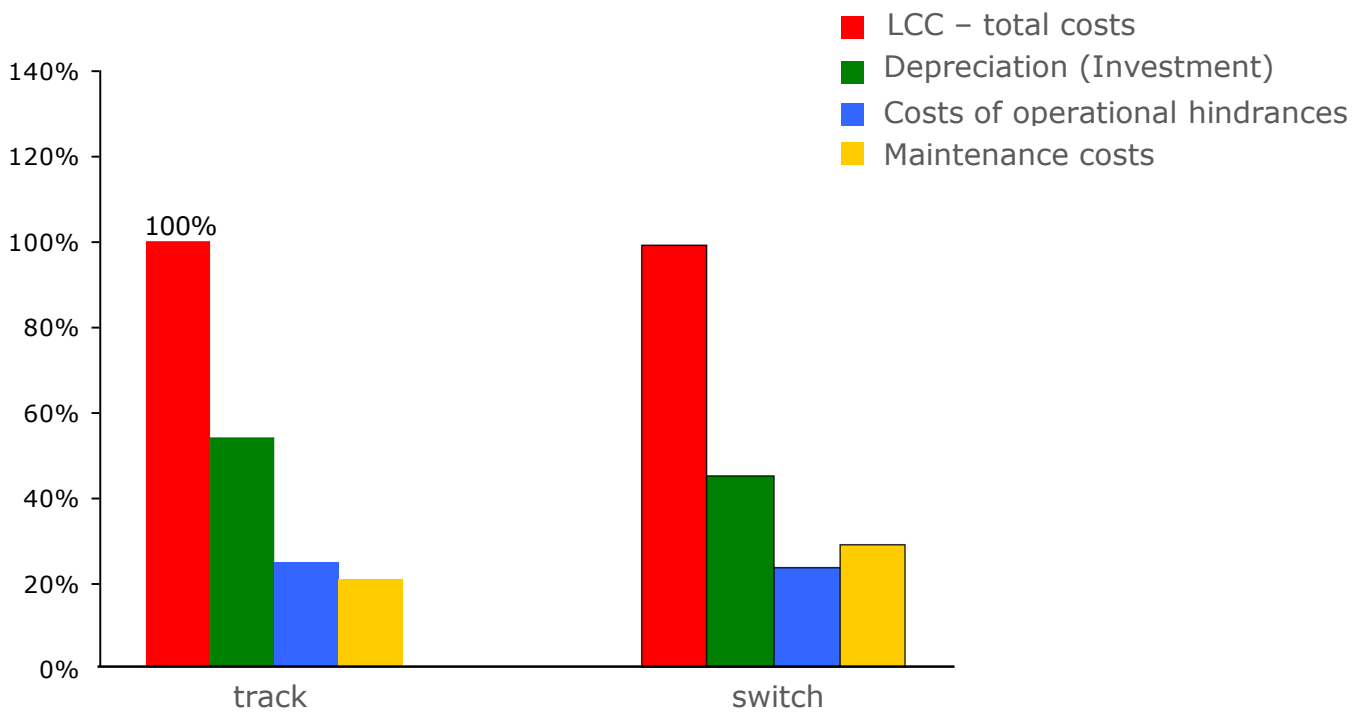
but react in the same way



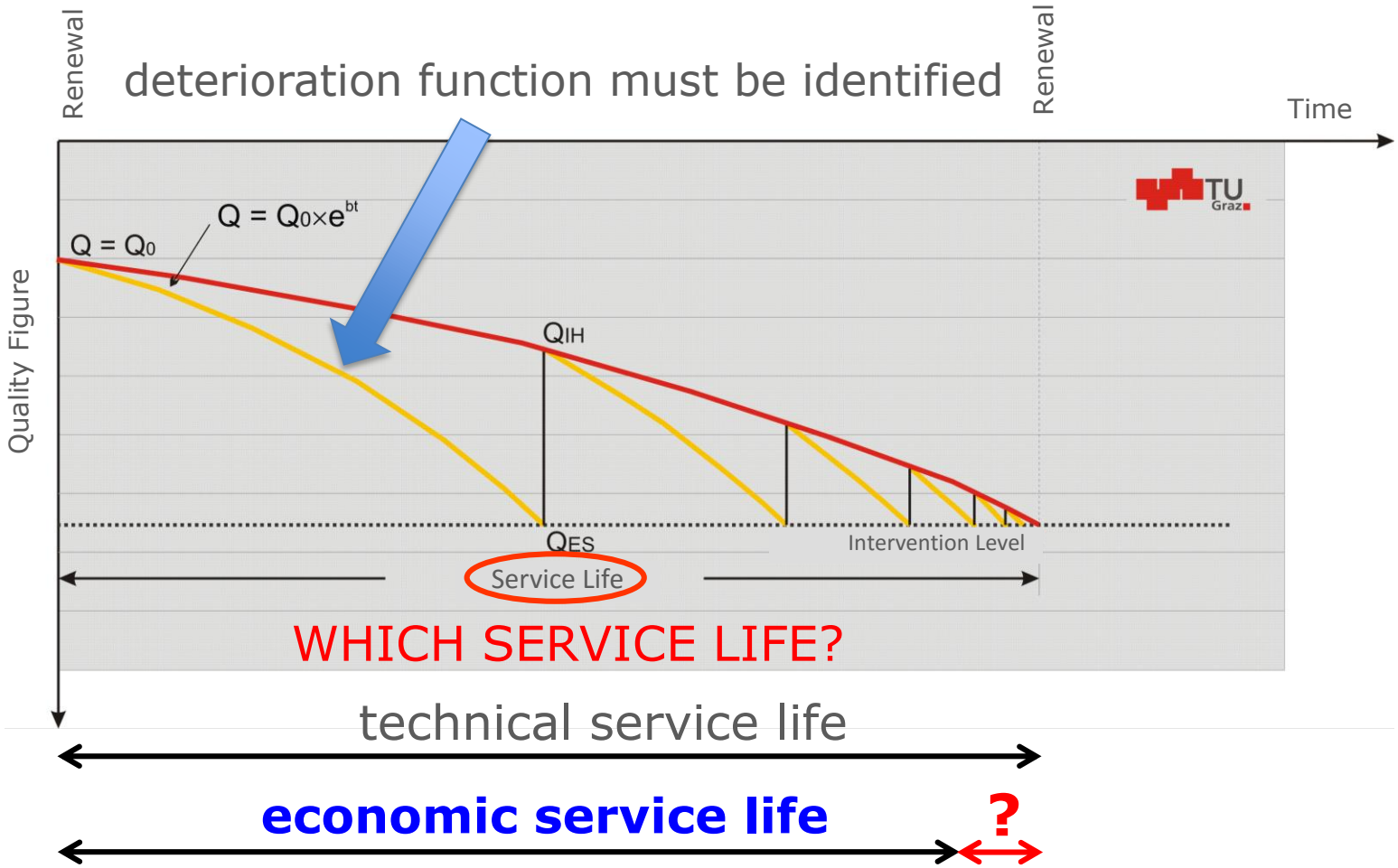
costs are totally different

Let’s transfer the experiences from track to switches!

Life Cycle Costs – Track versus Switches



Let’s transfer the experiences from track to switches!



Let's transfer the experiences from track to switches!

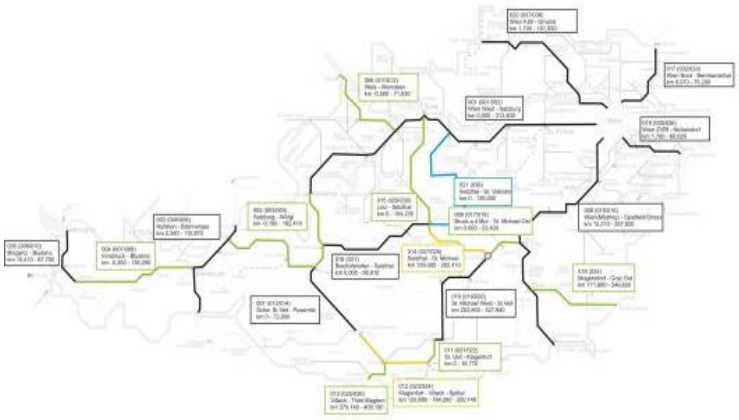
Identification of Deterioration Function

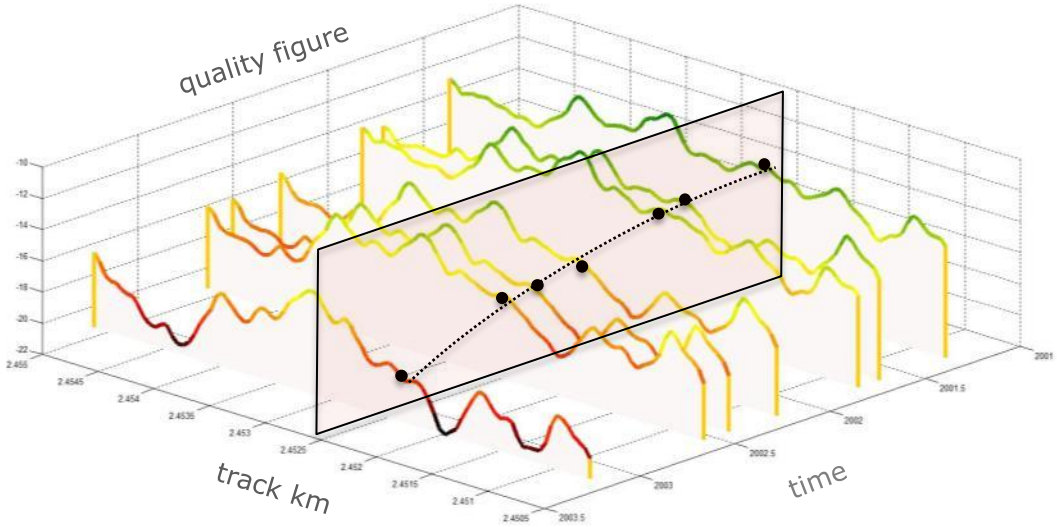
- Time sequences of recording car data (since 2001)

  additionally

  - type and age of track and its components
  - maintenance executed
  - alignment
  - transport data over time

- and everything for the entire Austrian core railway network

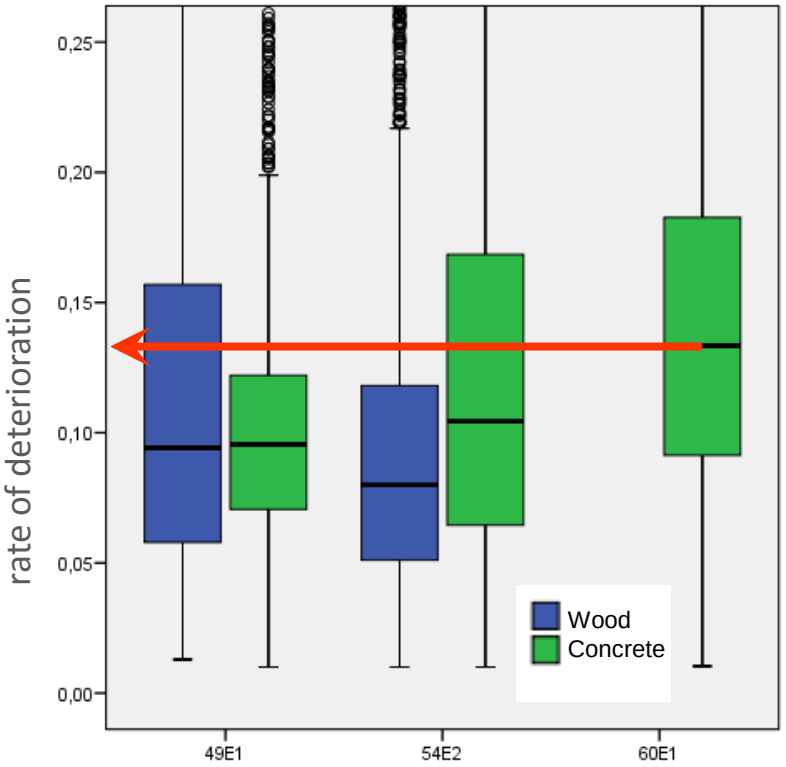




Analyses and Predictions are possible…

but might be wrong!

Example: influence of type of superstructure on deterioration rate



60E1 on concrete sleepers show highest rates of deterioration

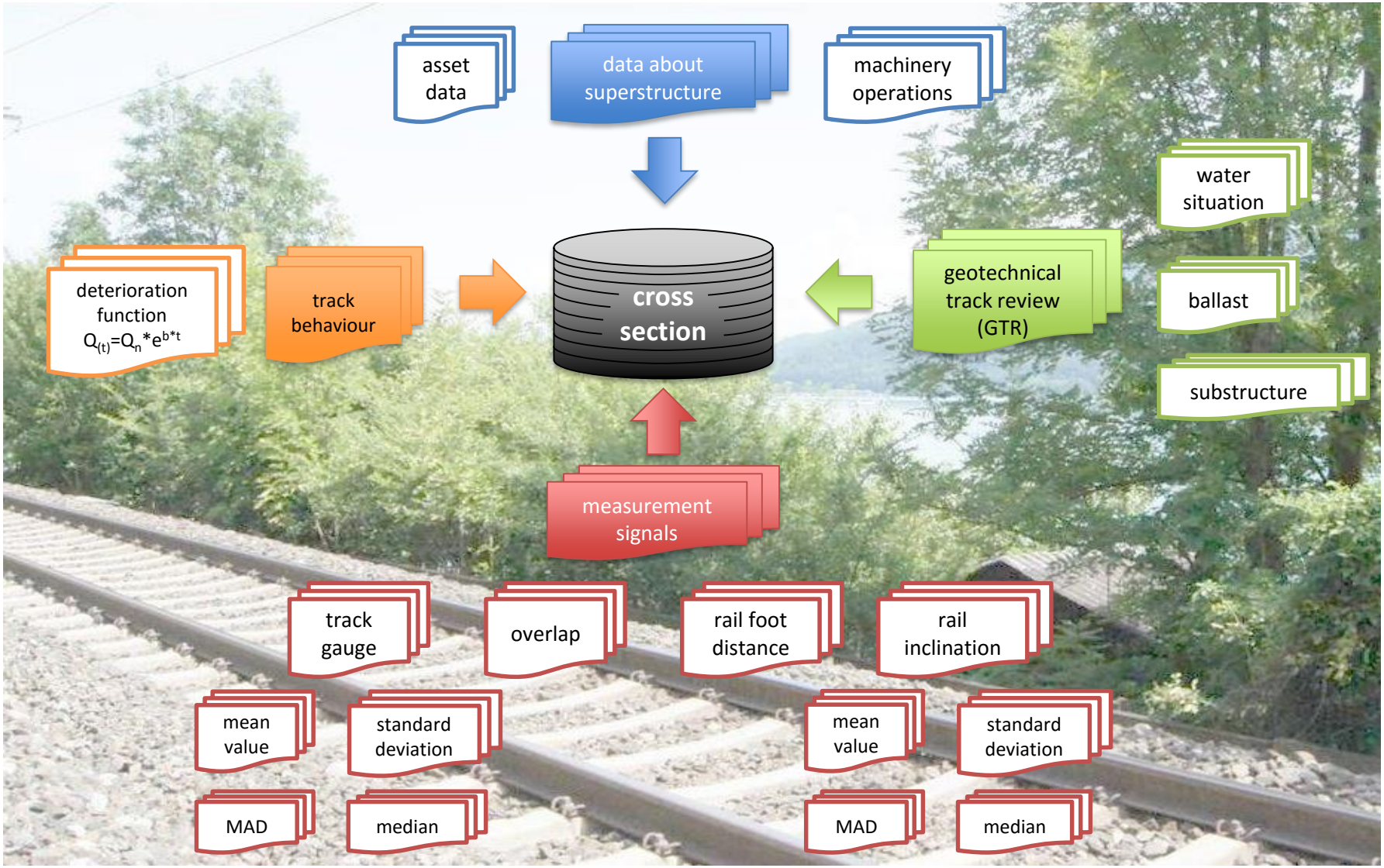
Expected - True?

Not considered:

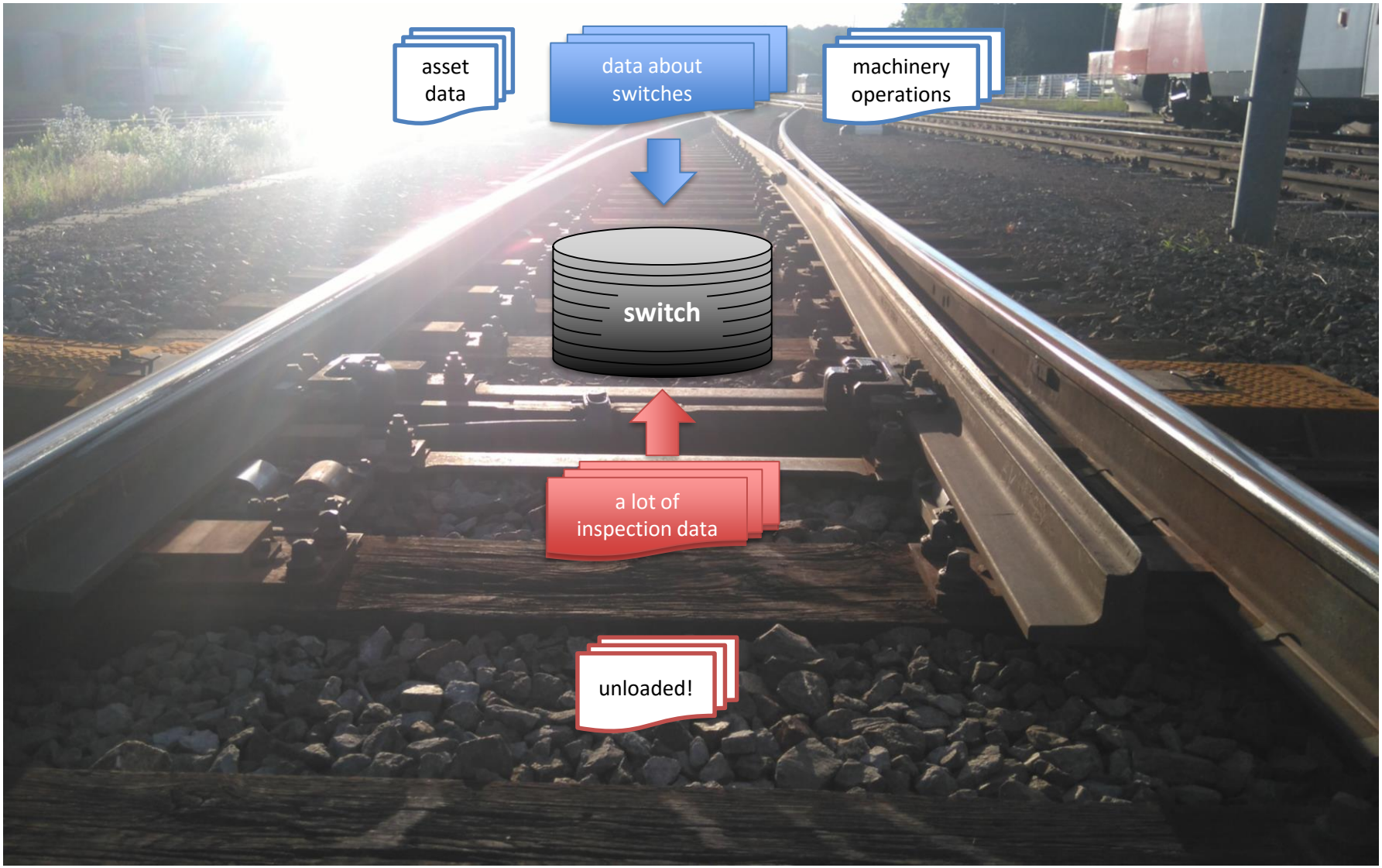
- Traffic volume
- Substructure
- Track Age
- Execution of maintenance

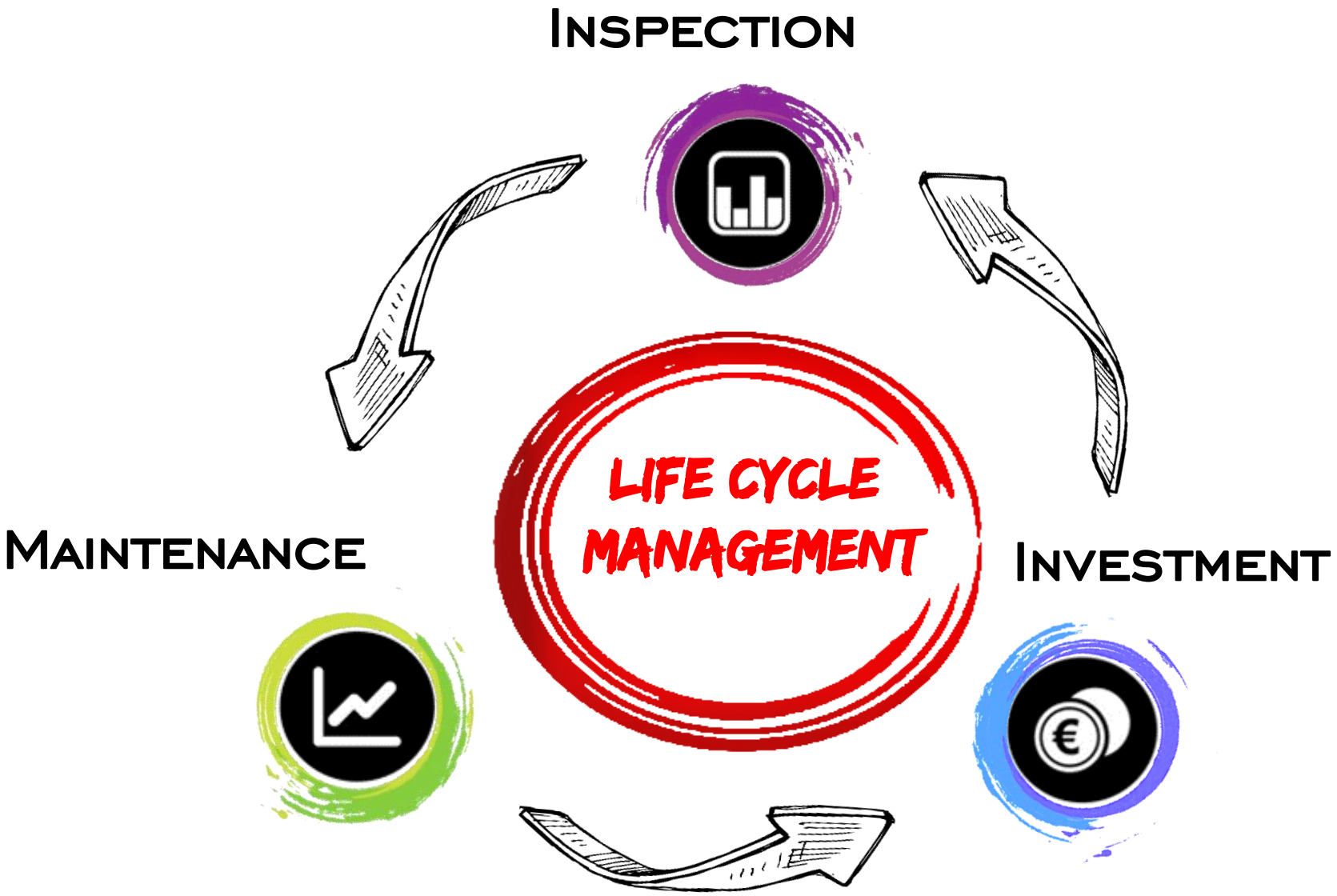
Analyses must always be parameter-specific ones!

Characteristics of Superstructure - Costs



Characteristics of Superstructure - Costs




INSPECTION
LIFE CYCLE MANAGEMENT
MAINTENANCE
INVESTMENT

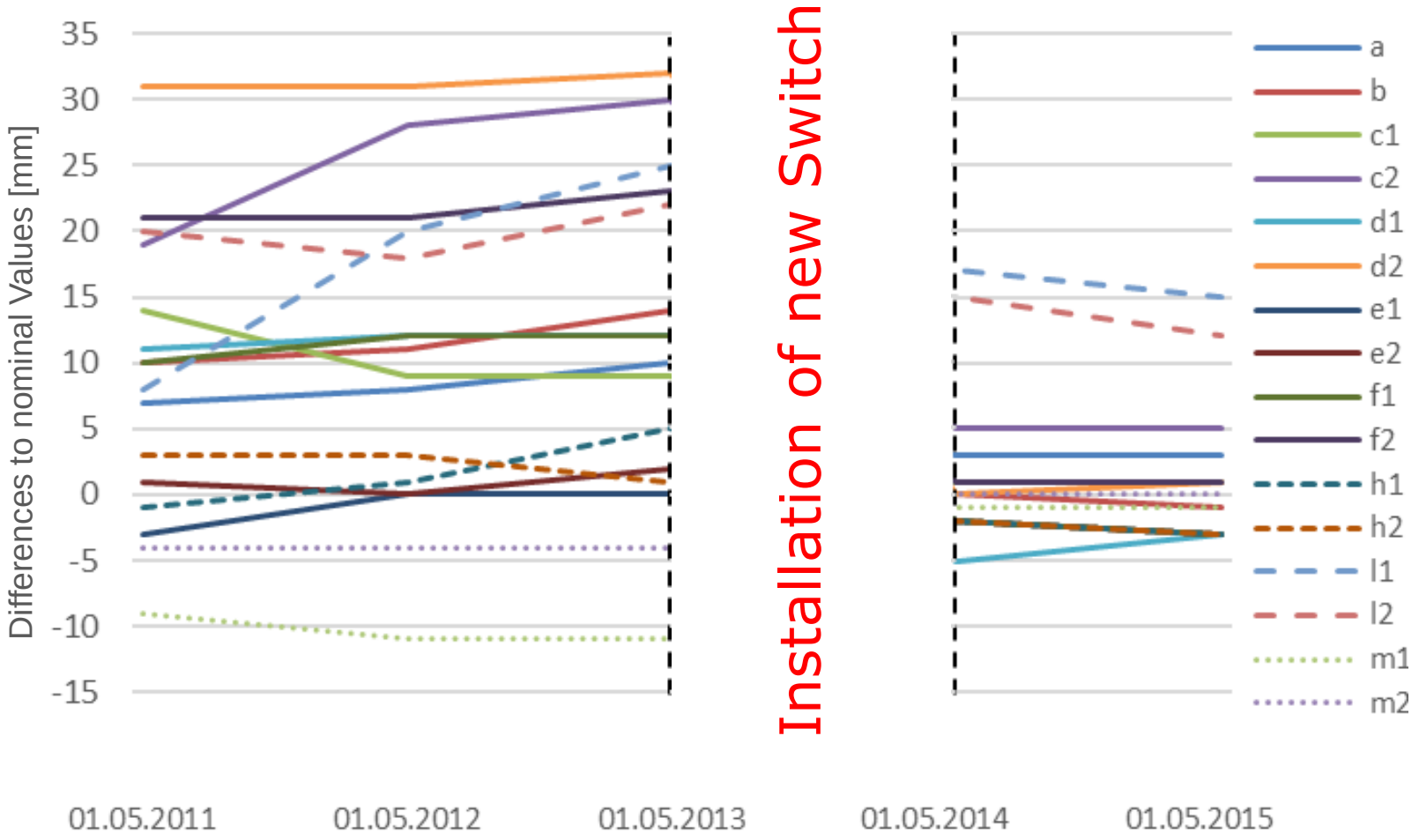
- Does the inspection data reflect the reality?
- Can a prediction model be built up based on data of unloaded measurements?

There are painfully many components!

And many of them are measured manually.

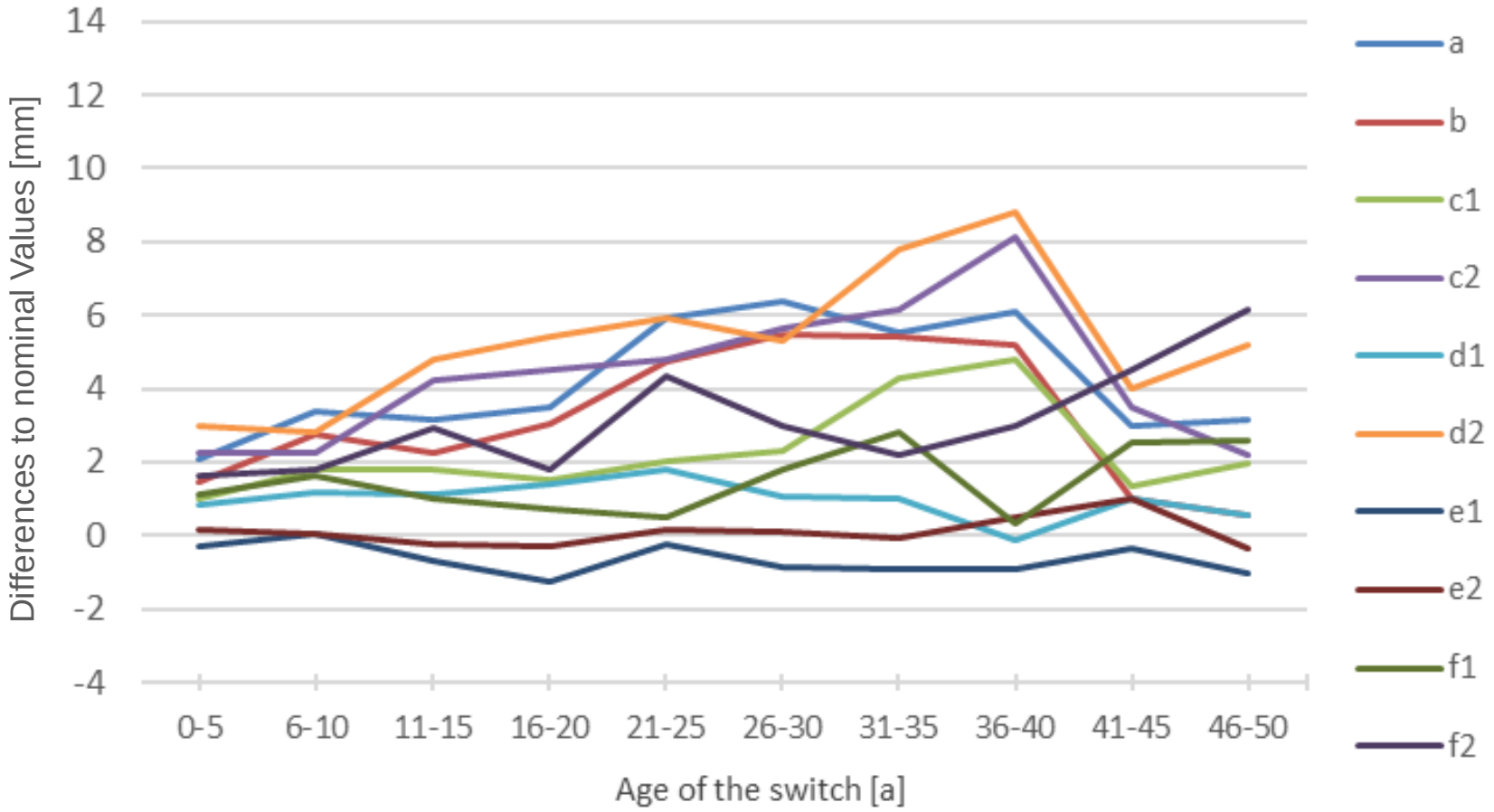
Checking data Quality – can Trends be Extracted?

- Time sequences of switch gauge measurements

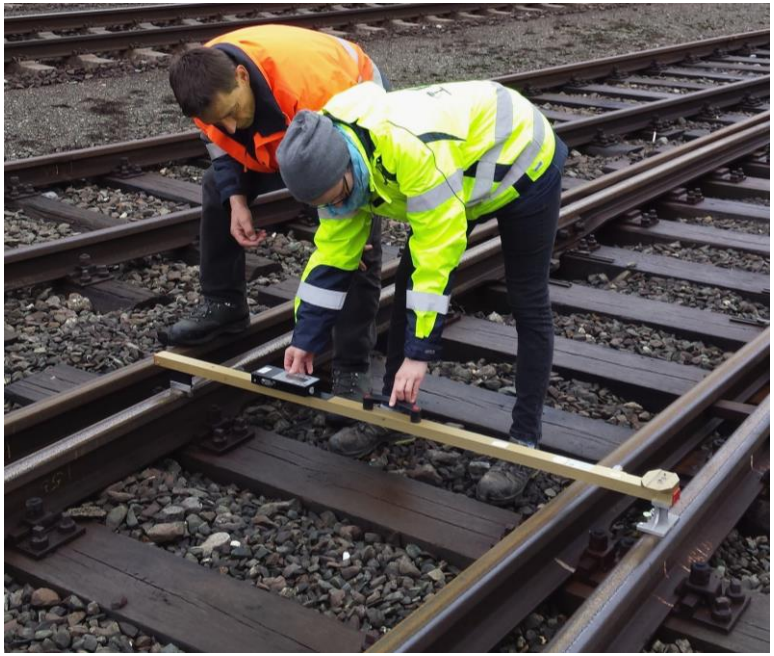


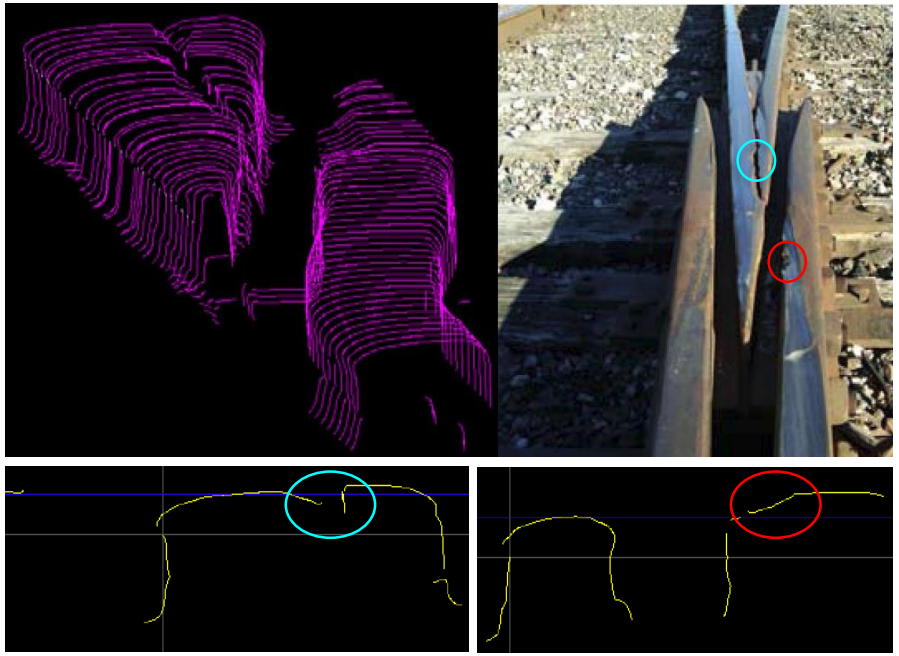
Checking data Quality – can Trends be Extracted?

- Deviation from nominal gauge over the service life



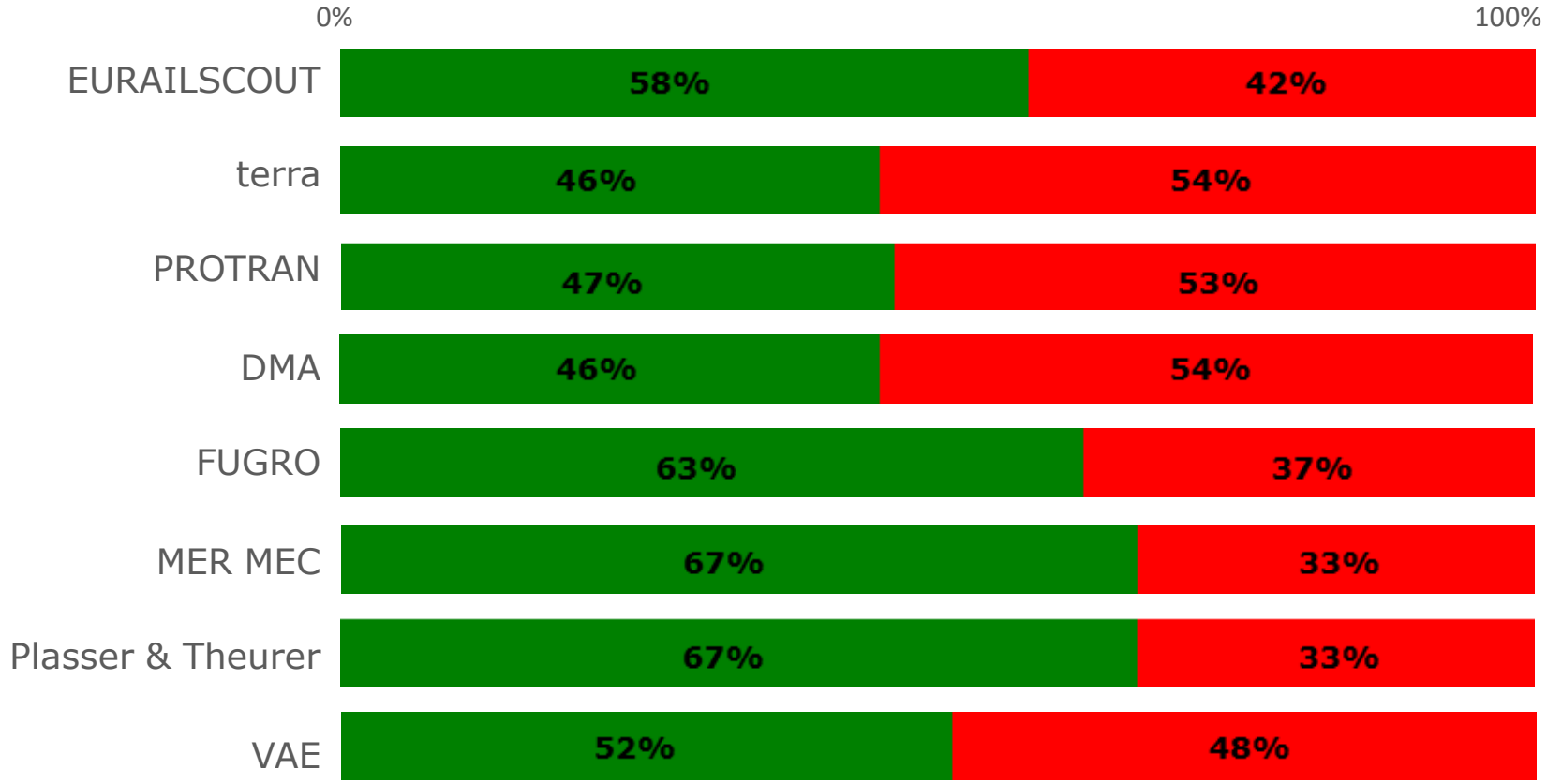
The way from a manual to an automated switch inspection





- no inspection staff is in the danger area
- loaded measurement
- repeatable
- objective observation

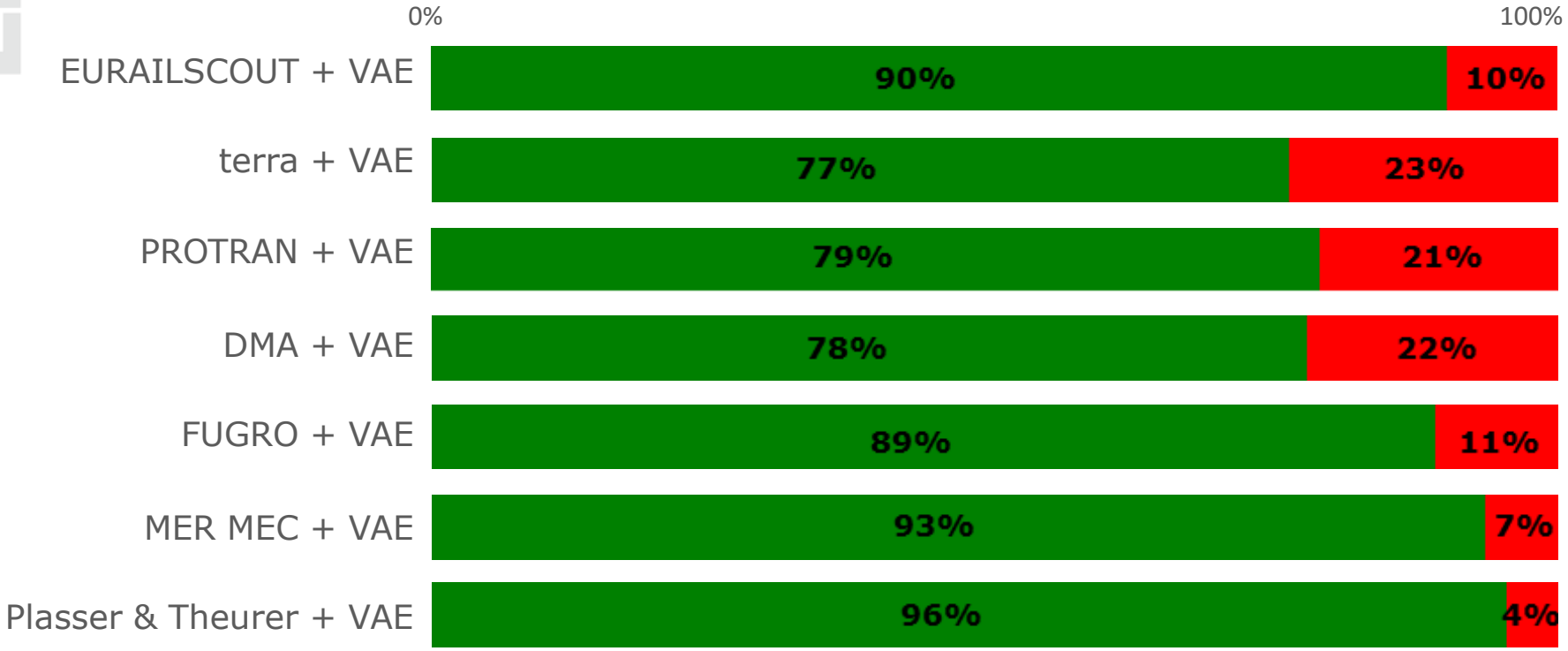
Innovation in Inspection



inspection tasks to be performed automatically

inspection tasks still require manual measurements

Innovation in Inspection

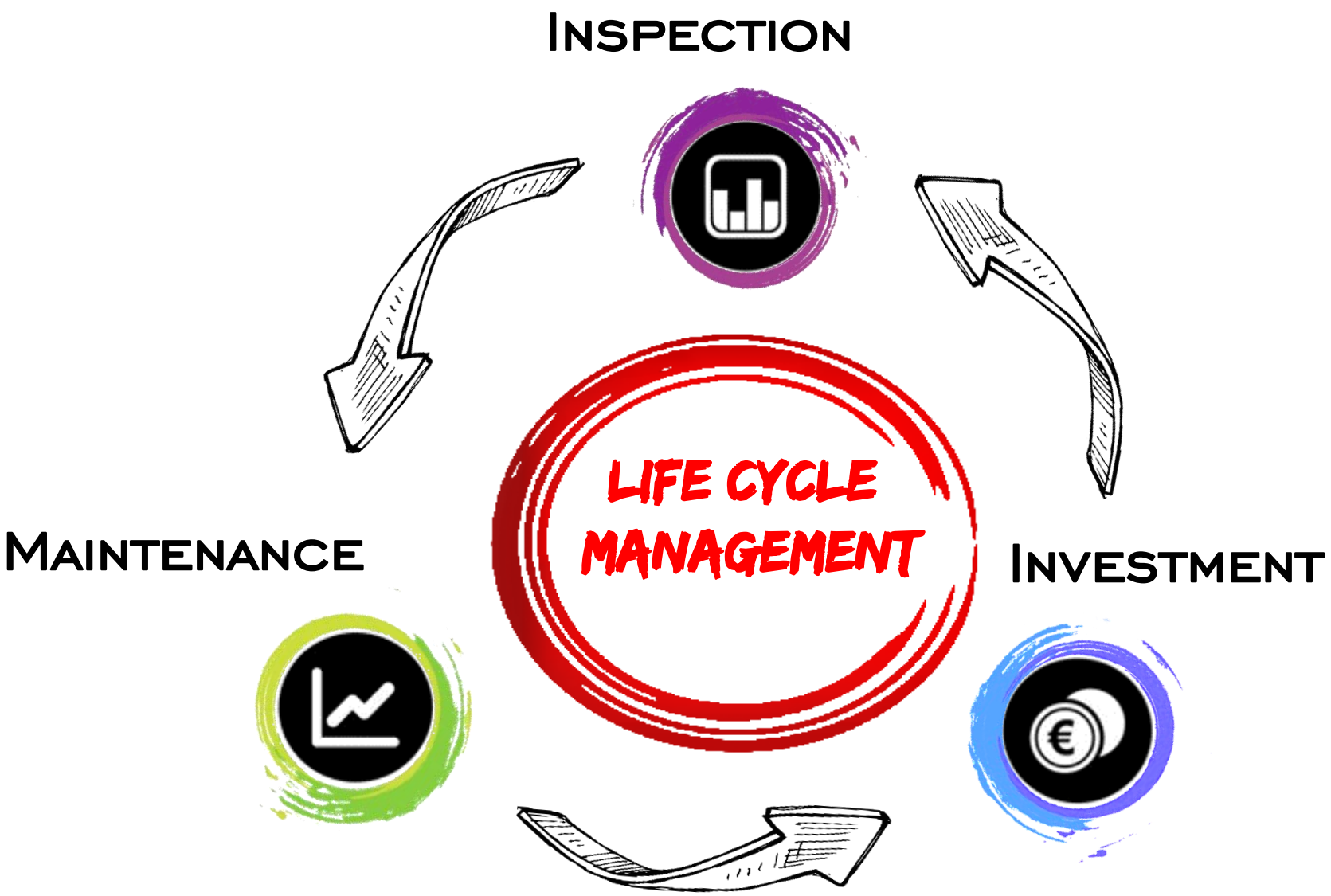


Combining existing recording cars and way-side monitoring systems deliver proper data!

inspection tasks to be performed automatically

inspection tasks still require manual measurements

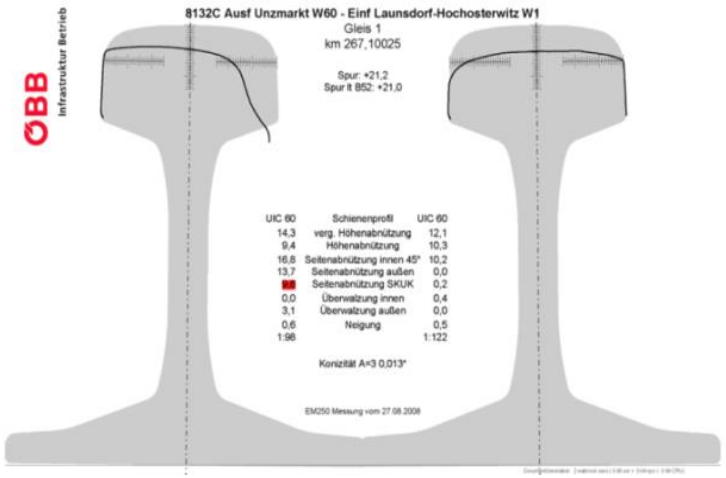
How can these technologies be implemented?


INSPECTION
LIFE CYCLE MANAGEMENT
MAINTENANCE
INVESTMENT

All inspected components also need maintenance

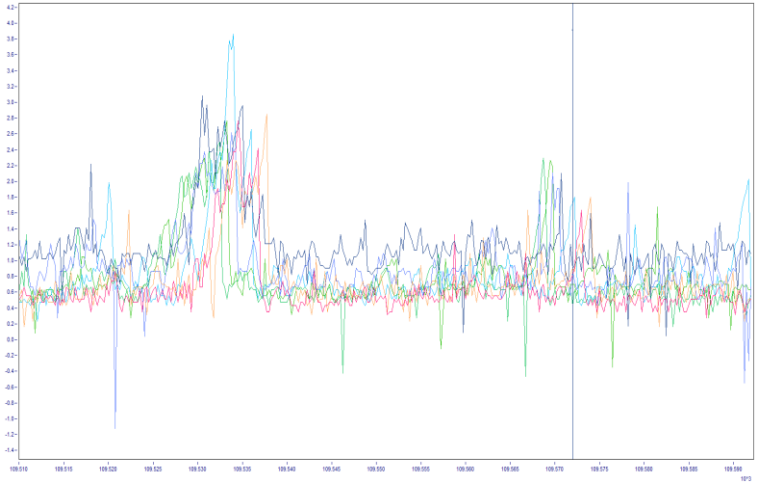
Condition Data – ready for Trend-Analysis?

object	track	switches	method
rail wear	✓	✗	rail profile scan



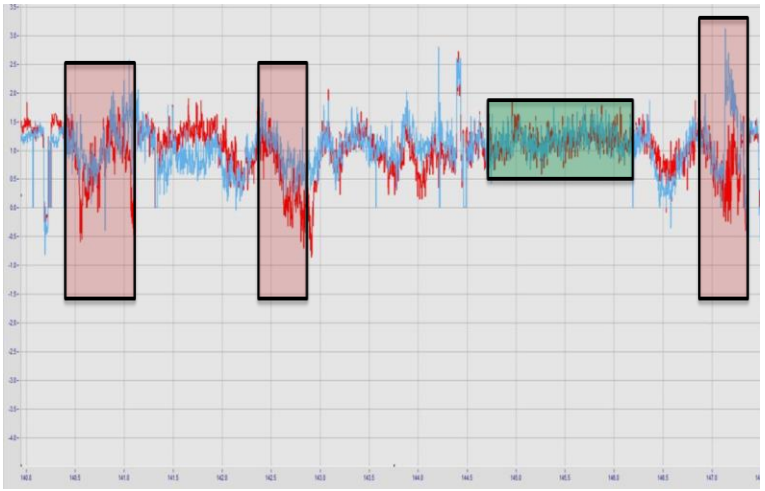
Condition Data – ready for Trend-Analysis?

object	track	switches	method
rail wear	✓	✗	rail profile scan
corrugation	✓	✓ ✗	acceleration signal



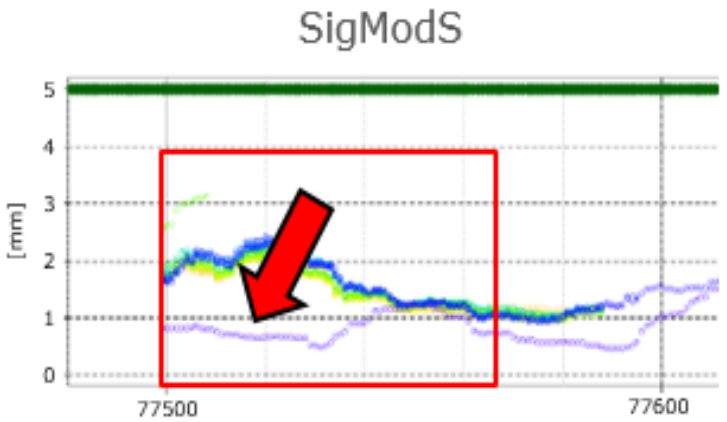
Condition Data – ready for Trend-Analysis?

object	track	switches	method
rail wear	✓	✗	rail profile scan
corrugation	✓	✓ ✗	acceleration signal
rail-pad	✓	✓ ✗	rail inclination



Condition Data – ready for Trend-Analysis?

object	track	switches	method
rail wear	✓	✗	rail profile scan
corrugation	✓	✓ ✗	acceleration signal
rail-pad	✓	✓ ✗	rail inclination
fastening	✓	✗	gauge signal modified



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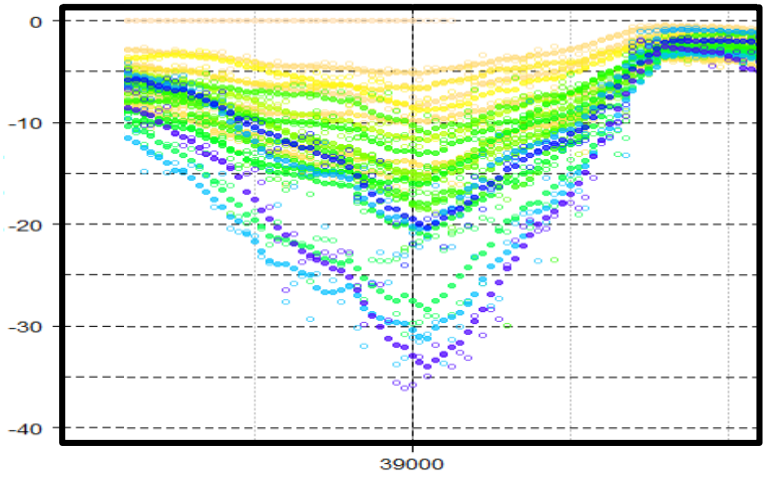
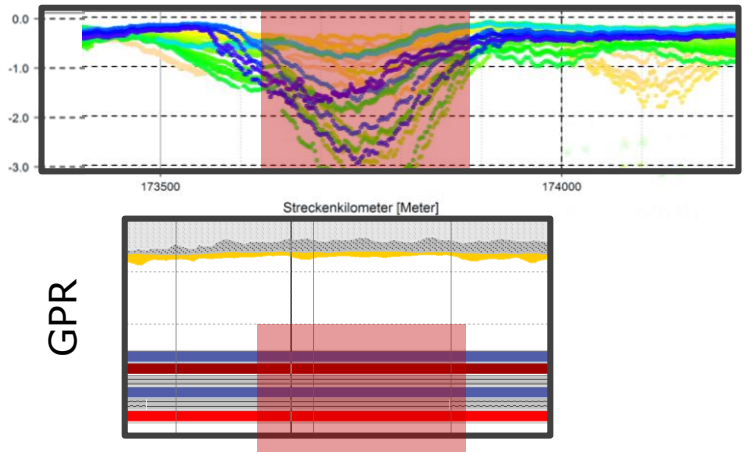
corrugation	✓	✓ ✗	acceleration signal
rail-pad	✓	✓ ✗	rail inclination
fastening	✓	✗	gauge signal modified
ballast	✓	✓ ✗	fractal analysis (longitudinal level)



Condition Data – ready for Trend-Analysis?

object	track	switches	method
rail wear	✓	✗	rail profile scan
corrugation	✓	✓ ✗	acceleration signal
rail-pad	✓	✓ ✗	rail inclination
fastening	✓	✗	gauge signal modified
ballast	✓	✓ ✗	fractal analysis (longitudinal level)
sub-layer	✓	✓ ✗	fractal analysis & GPR



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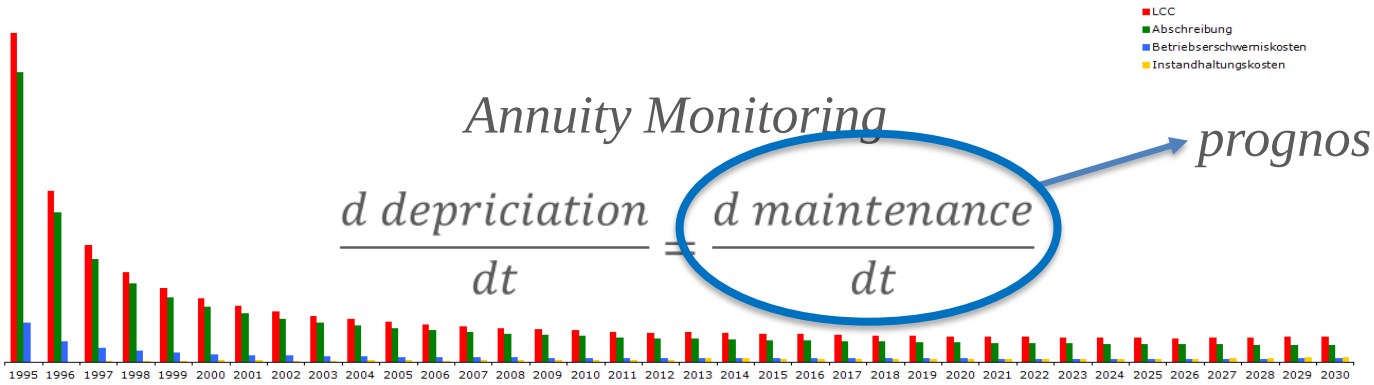
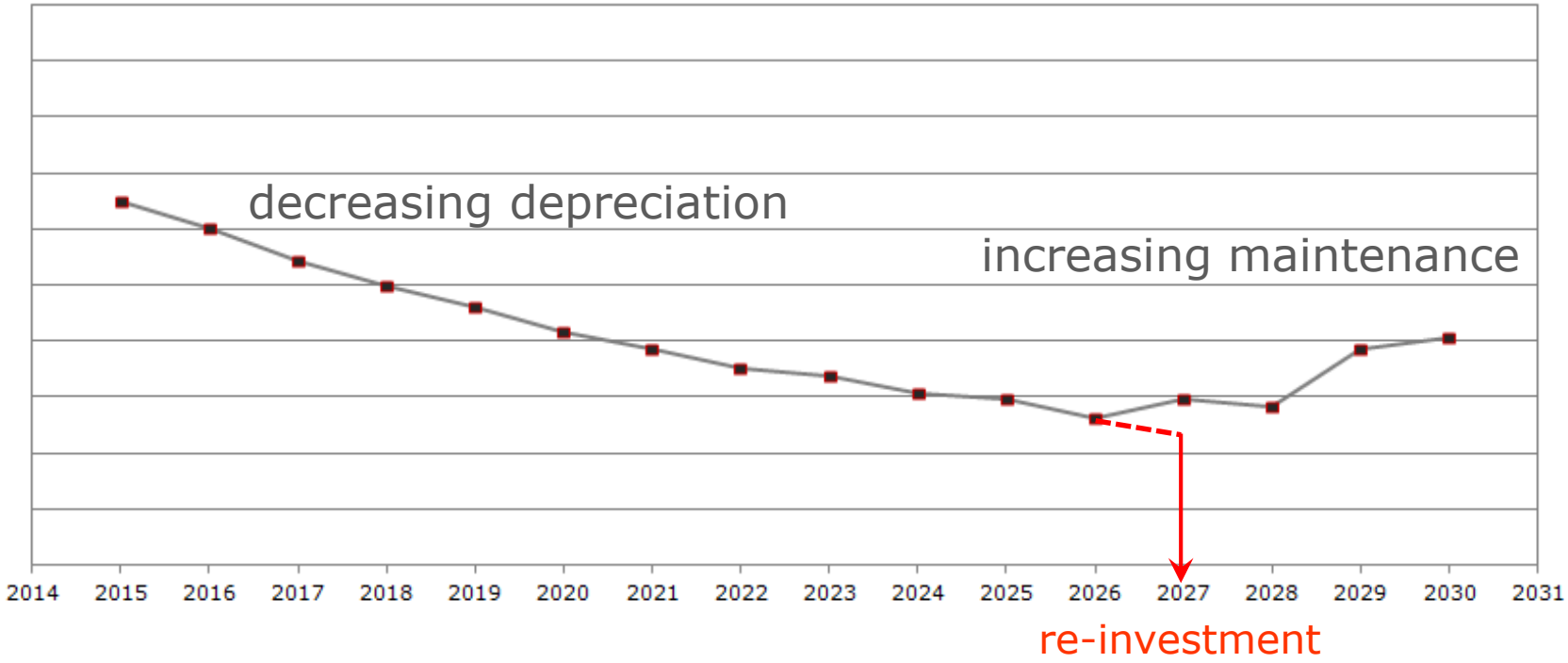
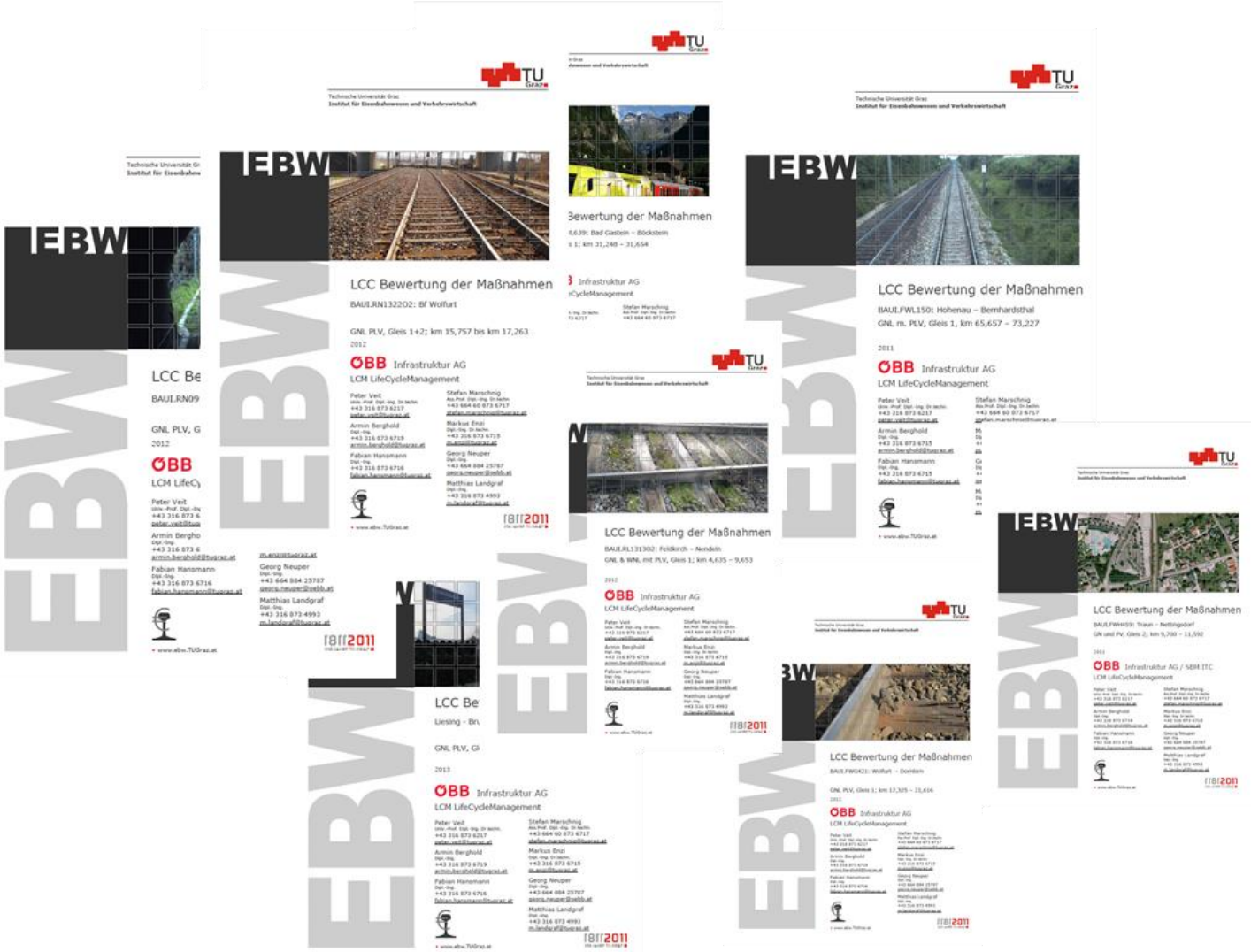
fastening	✓	✗	gauge signal modified
ballast	✓	✓ ✗	fractal analysis (longitudinal level)
sub-layer	✓	✓ ✗	fractal analysis & GPR

Measuring – Trend Analyses
Trend Analyses – Prognosis
Prognosis – Economic Service Life

Calculation of Economic Service Life





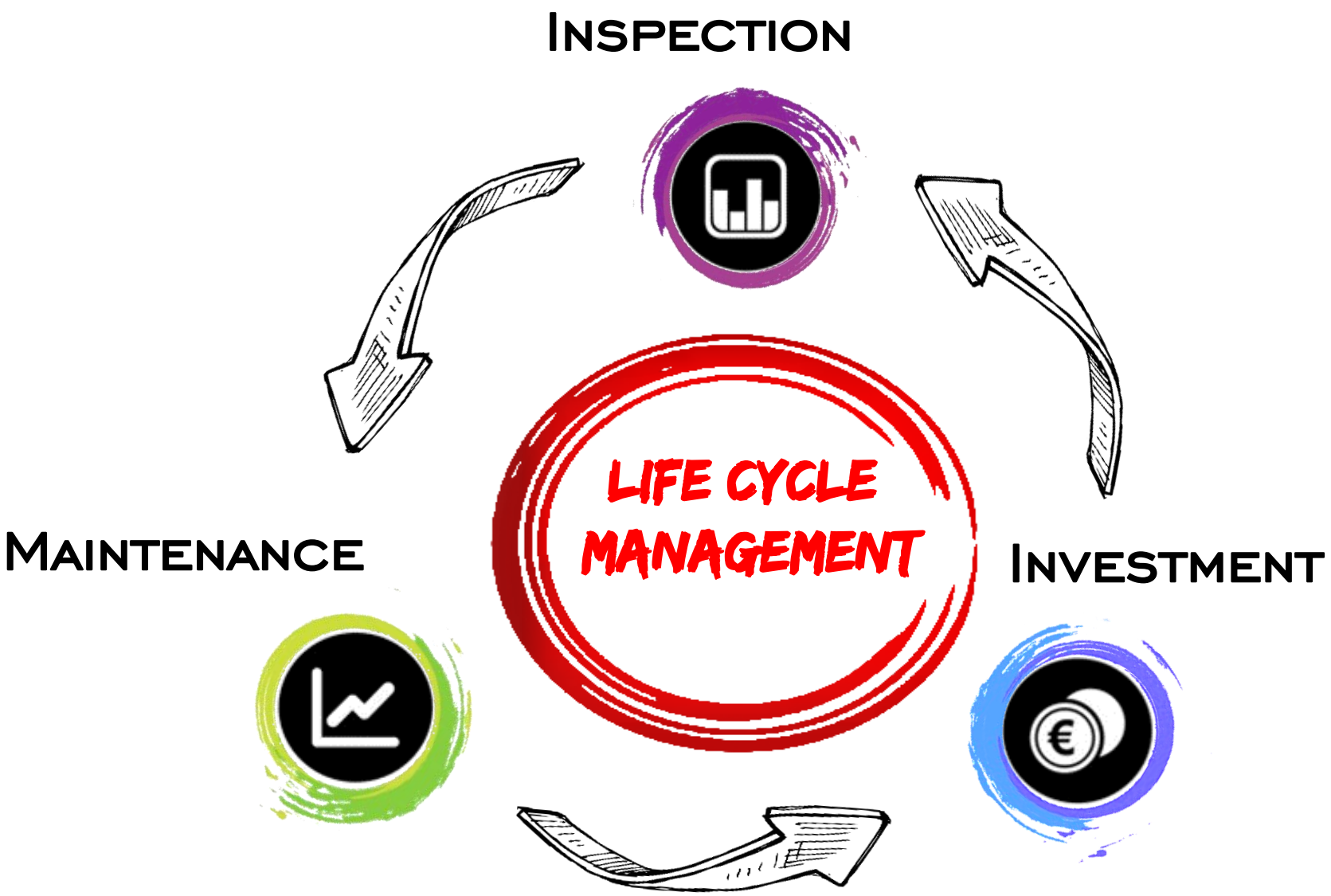


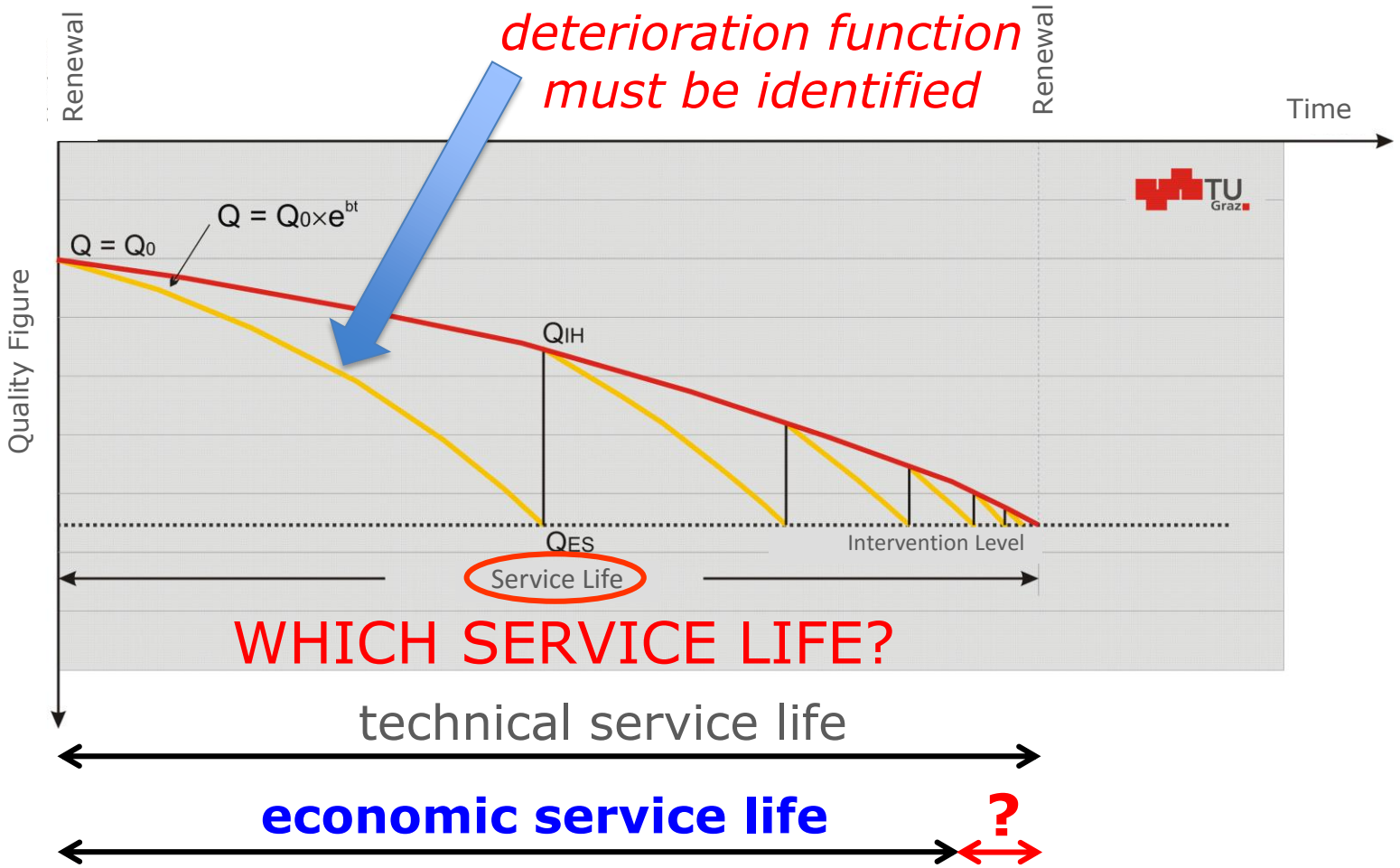
Implemented at ÖBB in 2011 for track projects.

Next steps to go

Example: evaluation of projects planned for 2018

project costs	point in time for reinvestment		damage [€]				ranking index
			2018/19	2018/20	2018/21	2018/22	
4.030.000	2016	●	1.122.618	1.252.498	1.626.974	1.877.760	27,9
3.600.000	2015	●	751.920	787.055	775.999	918.808	20,9
1.030.000	2018	●	162.272	150.664	145.727	141.120	15,8
1.225.000	2017	●	161.054	150.436	210.969	203.451	13,1
1.560.000	2018	●	86.435	74.020	138.707	122.052	5,5
4.900.000	2016	●	209.586	222.648	238.542		4,3
1.040.000	2018	●	38.671	32.885	50.480	40.936	3,7
8.160.000	2018	●	241.112	306.878	326.209	889.219	3,0
3.980.000	2018	●	102.786	47.754	140.988	128.075	2,6
918.000	2018	●	17.728	16.449	29.616	29.012	1,9
980.000	2018	●	15.500	7.190	38.983	31.163	1,6
1.030.000	2018	●	14.194	13.528	63.621	62.137	1,4
3.230.000	2016	●	-5.099	26.991	91.115	258.894	-0,2
4.460.000	2019	●	-15.615	-2.222	58.202	75.333	-0,4
4.460.000	2019	●	-18.136	15.011	-1.593	3.314	-0,4
4.750.000	2022	●	27.250	-24.913	13.253	-36.906	-0,8
5.997.215	2017	●	-53.893	3.335	123.670	220.922	-0,9
1.230.000	2021	●	-1.798	-9.945	-11.760	12.149	-1,0
6.230.000	2020	●	3.616	-63.807	-46.615	-20.688	-1,0
1.950.000	2022	●	24.609	-7.535	-36.008	-47.650	-2,4


INSPECTION
LIFE CYCLE MANAGEMENT
MAINTENANCE
INVESTMENT



Unfortunately this deterioration function is not yet identified.

By mischance, this deterioration function even does not exist.

Experiences of Railway Experts

Reasons for re-investing switches:

- fouled ballast
- worn-out sleepers
- pressed-in ribbed base plates
- loose fasteners
- unstable subsoil
- problems with dewatering system
- frog exchange
- tongue rail exchange
- entire rail exchange
- entire sleeper exchange

overall function cannot exist on technical behaviour only

forecasting of behaviour possible

however, exchange or re-investment depends on residual service life of structure → BALLAST

Ongoing Research

overall function cannot exist on technical behaviour only

- Integration of recording car data and switch monitoring systems

forecasting of behaviour possible

additionally

- type and age of switches and its components
- maintenance executed
- transport data over time for all directions

- and everything for numerous types of switches

Ongoing Research – Current topics

- specific turnout recording car or adaption of track recording car

- data collection, integration and preparation

- time sequences

Finally all preliminary work is done to transfer the experiences from track to switches!

Next steps to go

- time sequences

To build up time sequences of data requires time – which we definitively do not have!

service life	33,0	0	1	2	3	4	5	6	7	8	9	10	11		26	27	28	29	30	31	32
relaying of turnout	1,0	1																			
leveling-lining-tamping	5,5						1					1						1			
grinding	7,0				1				1				1			1					
exchange of half set of switches	2,0																				
exchange of frog	3,0									1					1						
exchange of checkrail	1,0																				
overlay welding/repair welding	3,0								1					1							
deburring	29,0		1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1
unplanned small maintenance	28,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5		1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
ballast undercutting/cleaning	0,0																				
rail pad exchange	1,0																				
sleeper screw hole renewal	0,0																				
exchange of set of sleepers	0,0																				
exchange of single sleepers	0,0																				

While doing that build up time sequences and do trend analyses, risk analyses, …

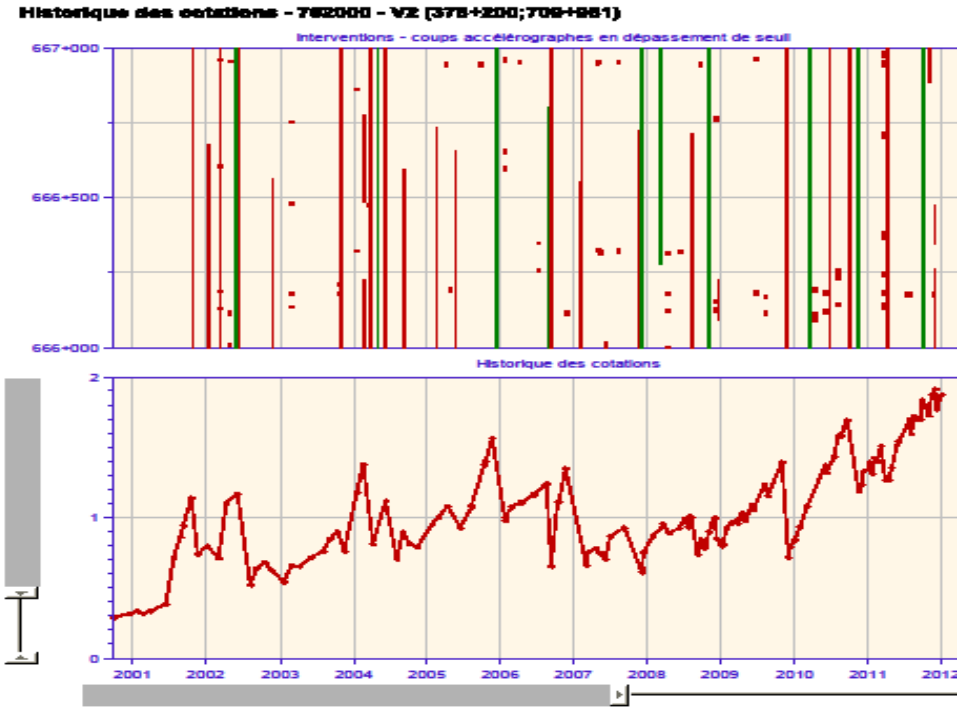
Cost Driver

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

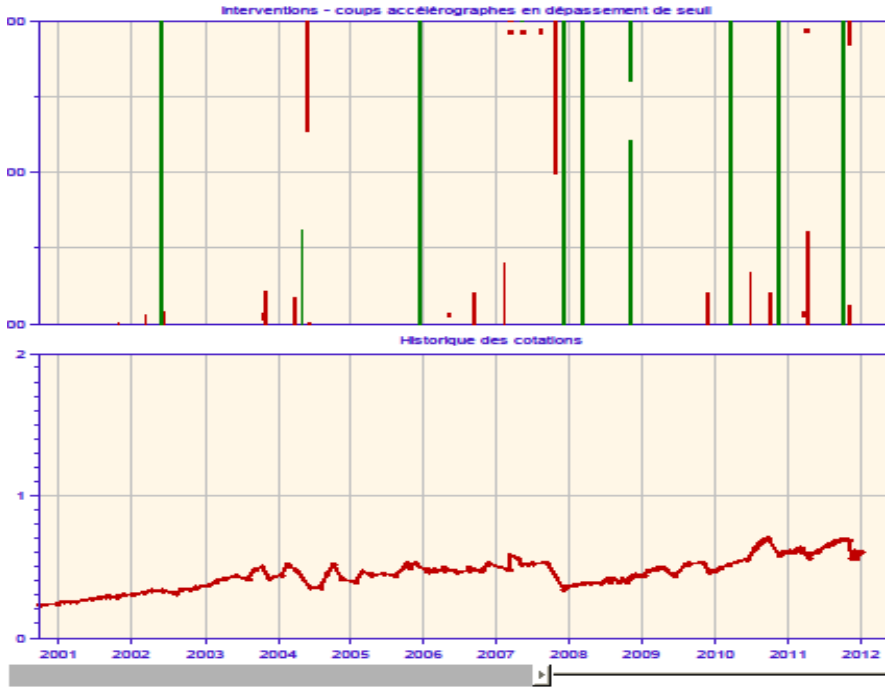
While doing that build up time sequences and do trend analyses, risk analyses, …

Track Behaviour

without USP



with USP



intervention level: σ_v = 1.3 mm (1 km)

intervention level: σ_v = 0.6 mm (1 km)

While doing that build up time sequences and do trend analyses, risk analyses, …

Turnout Strategy based on LCC – Evaluations

Moveable frog for turnouts in tracks with speeds lower than 200 km/h:

for tracks with loads of more than 70.000 gross tons/day…

… if there are no major (costly) changes in the control centre required!

While doing that build up time sequences and do trend analyses, risk analyses, …

Wear Model on TAC

$$C_V = k_{1_R} \times P_{2,V}^{\ 3} + k_2 \times P_{2,V}^{\ 1,2} + k_3 \times T_{pv} + k_{4_R} \times W_{b_R} + k_5 \times \sqrt{\left(0.5 \times P_{2,40kmph}^{\ 2} + 0.5 \times Y_{qs_{T\text{-}R185m}}^{\ 2}\right)}$$

Tamping

Straight

Curve

Grinding

Switches

Exchange of Rails

1.1.2017 implemented in Switzerland

While doing that build up time sequences and do trend analyses, risk analyses, …

Thanks for listening…

… and Thanks to all Research Partners

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BANE NOR
HOLDING GRAZ LINIEN
ÖBB
Rail Cargo Austria
SPOORNET
Infrastruktur
HŽ INFRASTRUKTURA
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