Project no. TIP5-CT-2006-031415

INNOTRACK

Integrated Project (IP)

Thematic Priority 6: Sustainable Development, Global Change and Ecosystems

D1.2.2

Track Sections and Track Irregularities Analysis of DB Sites

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
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Glossary

Terms and definitions

The following table summarizes the English and related German terms used in this report. The table should be extended for other languages to ensure a common nomenclature. This table does not replace the UIC dictionary but should support a common language in this WP.

English	**German**	**Swedish**
Vertical profile	Längshöhe, Vertikalprofil	vertikalprofil
Horizontal profile, alignment	Richtung, horizontale Pfeilhöhe	horisontalprofil pilhöjd
Track gauge	Spurweite	spärridd
Superelevation, cant	Überhöhung	ralsforhöjning
Curvature	Krümmung	kurvradie
Twist	Verwindung	
Under ballast mat	Unterschottermatte	ballastunderlägg
Under sleeper pad	Schwellensohle	slipersunderlägg

The terms *segment* and *section,* used in this report, should be interpreted as follows:

Segment – segment means a part of a system, defined by a set of *parameters*. The system is described by several segments. All sections with same parameters are the same segment.

E.g.: all straight line sections with identical track parameters and operational and boundary conditions are described by one segment. In the InnoTrack project it is assumed that all sections within one segment behave very similar and require similar maintenance.

SEGMENT = FUNCTION OF (IDENTICAL TRACK PARAMETER, IDENTICAL OPERATIONAL CONDITIONS)

Section - section means a part of a system that is described by a special *long-term behaviour and set of parameters.* A system is divided into a sequence of sections.

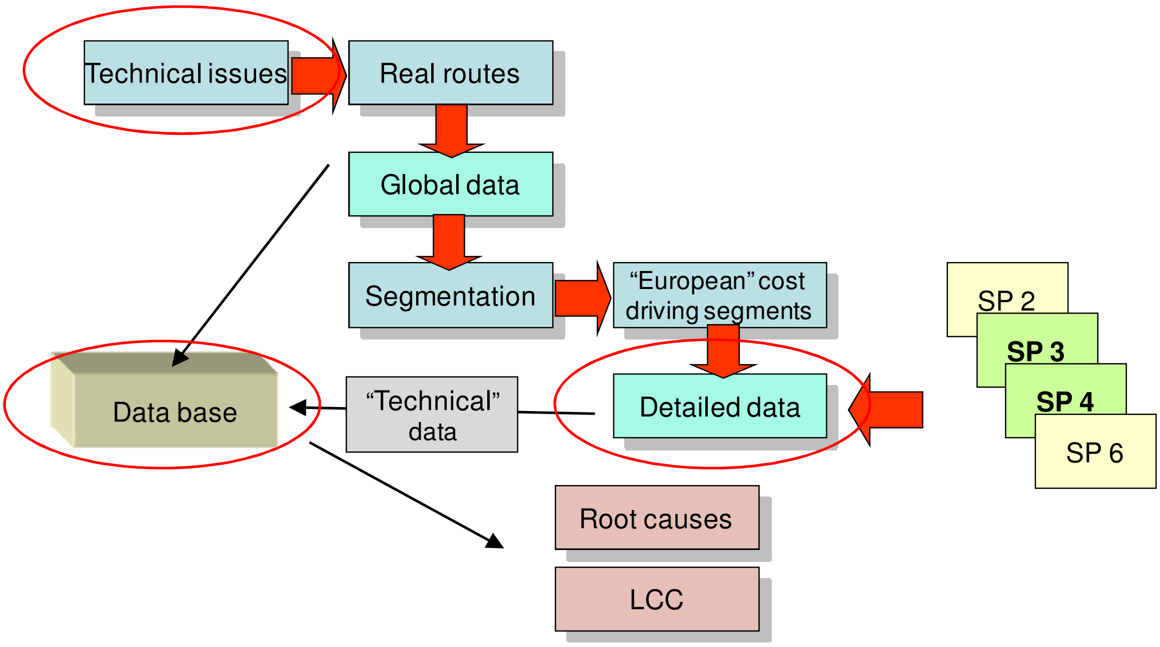
E.g.: a straight line with same parameters and boundary conditions and different long-term behaviour is divided into several sections.

SECTION = FUNCTION OF (BAD LONG-TERM BEHAVIOUR AND STRONG MAINTENANCE WITH ECONOMICAL IMPACT)

1. Executive summary

Track segments or track sections with major impact on life cycle costs are the basis for the work in InnoTrack. The following diagram shows schematically the accepted workflow for gathering data in the project. Start point of the analysis were the technical issues worked out during the IM's workshops of the different railways involved in the project.

During the workshops the IM's should select up to 3 sites, which should relate to the technical issues. From a "global view" taking into account the track layout, track design and operational parameters segmentation should be carried out for those routes and the cost driving segments should be identified. The comparison between all IM's lead either to "European cost driving segments" or to the question of best practise.



For the identified cost driving segments detailed data should be gathered and provided to the technical subprojects for further analysis and technical optimisation. The workflow is described on the next page.

The most important result of the detailed track analysis at DB is that a general segmentation failed. The reason for this is that the track behaviour and required maintenance does not only depend on the place (track parameters and operationally parameters) but on the time (history of maintenance and maintenance strategies). Due to the unknown history of maintenance a sufficient accurate identification of segments is quite more complicated or impossible. A general decision for products or processes *for existing lines* on the basis of segments does not ensure an optimum regarding LCC.

The following report presents the results of the detailed technical and economical analysis of DB sites, selected during the IM workshop. For technical issues with economical impact related track sections were identified and all available and validated data are collected and provided to the common data base.

This version includes only results of the track. Results of the analysis for the switches and crossings, which were carried out in cooperation with subproject 6 *LCC assessment* are presented in the report D3.1.2.

Workflow

Workflow

- Identification of **"European" problems** with economical impact
- Selection of **routes** representative for technical problems
- **Segmentation** of routes
- Identification of **"critical" segments** (costs)
- Gathering of detailed data for "critical" segments for SP2/3/4/6
- Identification of **root causes** (product, procedure)
- **LCC analysis** for existing systems
- Development of **technical solutions** (product, procedure)
- **LCC and RAMS – analysis** for technical solutions

Note:
Due to the close relationship between the cost driving track segments and the track irregularities promoting failures and degradation the reports D1.2.2 and D1.2.3 are merged.

2. Introduction

The idea of track segmentation – a major task of InnoTrack - is a powerful approach to optimise relevant segments and to generate LCC optimised standards and rules for the different segments. This approach requires a definite identification of segments on the basis of technical data like track and operational parameter and similar long-term behaviour of track sections subsumed in one segment. If global segmentation is possible with an efficient accuracy, the reduction of LCC for the segment is transferable to the whole network without the need of local decisions. The solution can be implemented in national and international standards and rules.

Corus introduced and use data mining functionalities for the identification of track segments [see Report on track segmentation]. This method shapes up as a very interesting and powerful approach because data mining enables *descriptive* and *predictive* analysis. The descriptive analysis of data mining tools was used to identify track segments.

3. Track analysis

3.1 Approach

Intention of the work package 1.2 – track characteristics - in the subproject 1 - in the first year of the project is to determine typical railway track segments with major maintenance-activities, maintenance-costs or influence on life cycle costs and provide track characteristics data for the analysis of these segments in other specialised subprojects of InnoTrack.

Each participating railway company should select up to three different railway track lines and make their segmentation according to the collected track data.

The basis for the selection of the analysed lines is the result of national workshops with infrastructure managers, which took place at the beginning of the Project InnoTrack. In the national workshops maintenance issues have been discussed, which have an economically and operationally relevance for the national railway companies and which should be addressed to the Project InnoTrack for analysis and optimisation. The selected lines should contain all typical national maintenance issues, which cause high maintenance cost or have a high operational or technical relevance for the national railway company.

3.1.1 Track segmentation - Top-down approach

At the beginning of the Project InnoTrack the originally fixed approach for the determination of typical line sections with intensive maintenance-activities and maintenance-costs was the so called Top-Down-Approach.

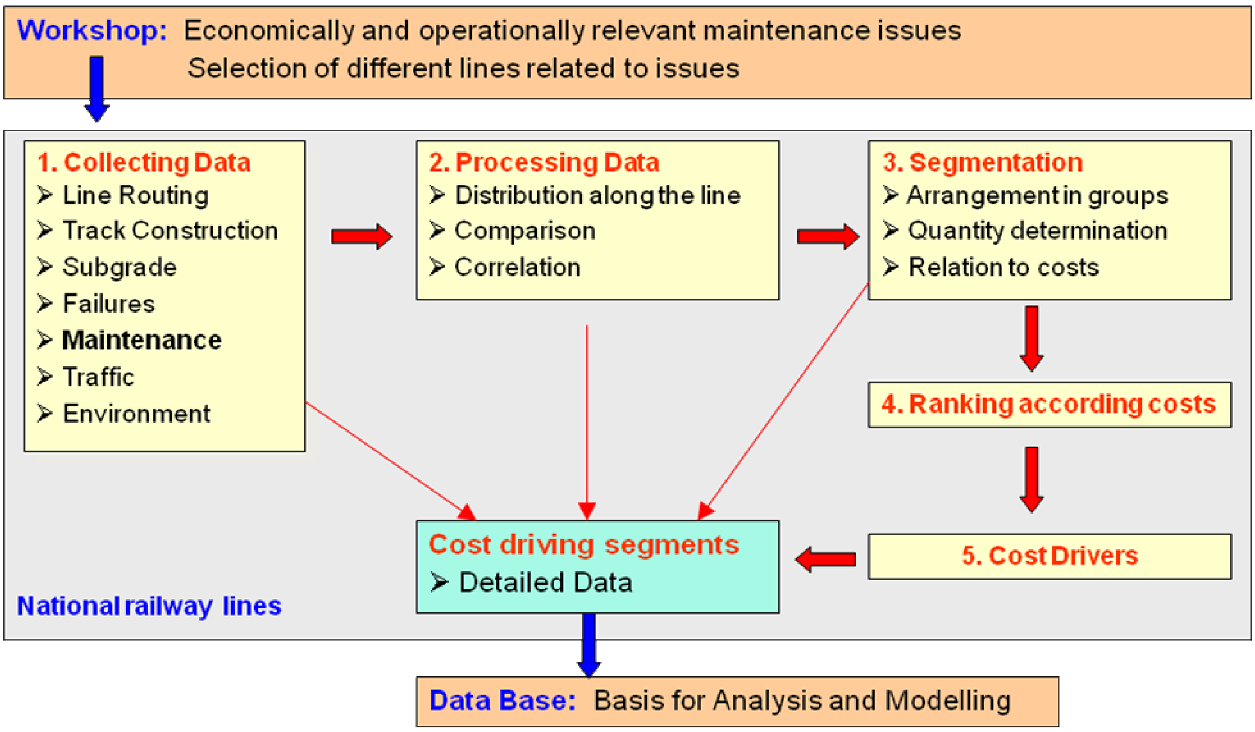


Figure 1: Schematic illustration of top-down approach

The intention of the Top-Down-Approach was to collect all relevant data of the selected track, to make data distribution and data correlation along the line and to divide the line into line sections with the same characteristics. Arrangement of sections in groups - the segments - with the same characteristics should be done with a perspective view from the top.

The intention of the next step was to determinate the quantity structure of segment groups and their relation to maintenance costs. Ranking of segment groups according to costs should be done through multiplication of amount of segments and the segment maintenance costs.

Only the segment groups with cost drivers (and extraordinary some other segment groups with operationally or technically very important maintenance issues) should be described in detail through one typical example segment. For the selected example the following data should be provided: line routing, track construction, subgrade data, data about current failures and failures history, maintenance activities data (with time, costs and history specification), traffic data and data about environment.

With the collected examples and their detailed data from all participating railway companies a European data base for analysis and optimisation of maintenance and track construction should be designed.

The necessary terms for the effective implementation of the described top-down approach are:

- existence of detailed data for the whole line
- available history of maintenance activities at least for the last 5 years,
- continuous (consistent) maintenance praxis (timely, addicted to failure)
- *high correlation between line routing data, track design parameter, operational conditions on one hand and long-term behaviour and maintenance on the other hand*

The first DB railway track line which was selected for the analysis is a high speed line with a comparatively good availability of data in the data base SAP-R3 Netz and local track offices. The data base contains data regarding the technical parameters and the maintenance of the site on the basis of technical places, which includes track sections with different length. Amongst others, the availability of data and the well known track design parameter and substructure design was one of the reasons for the selection this line.

Disadvantage of the DB SAP-R3 data base is that the system is only several years old and therefore the time period with reliable maintenance data is limited: from the beginning of the year 2005 until now. So now we have an available history of maintenance from DB SAP-R3 data base for maximum 3 years. Longer history of failures and maintenance were obtained from infrastructure managers, provided, if they have saved their documentation.

As mentioned before, all available data of the selected line were collected and processed with a data mining system that enables

- an easy creation of data flows,
- execution of simple and complex analysis steps, and
- investigation of the results through interactive views on data and models.

Among visual analyses the following methods are used to identify segments of the line

- Linear correlation – which calculates a correlation coefficient, for the different parameters
- Crip Clustering using K-means that assigns a data vector to exactly one cluster.
- The fuzzy c-means algorithm, an unsupervised learning technique that can be used to reveal the underlying structure of the data and
- Probabilistic Neural Networks.

To give an impression of the complexity of the used analysis **Figure 2** shows a cut-out of the data workflow used for analysing the track geometry in relation to the track design, operational conditions, maintenance activities and maintenance costs. On the left side the input data and on the right side one part of the analysis is shown.

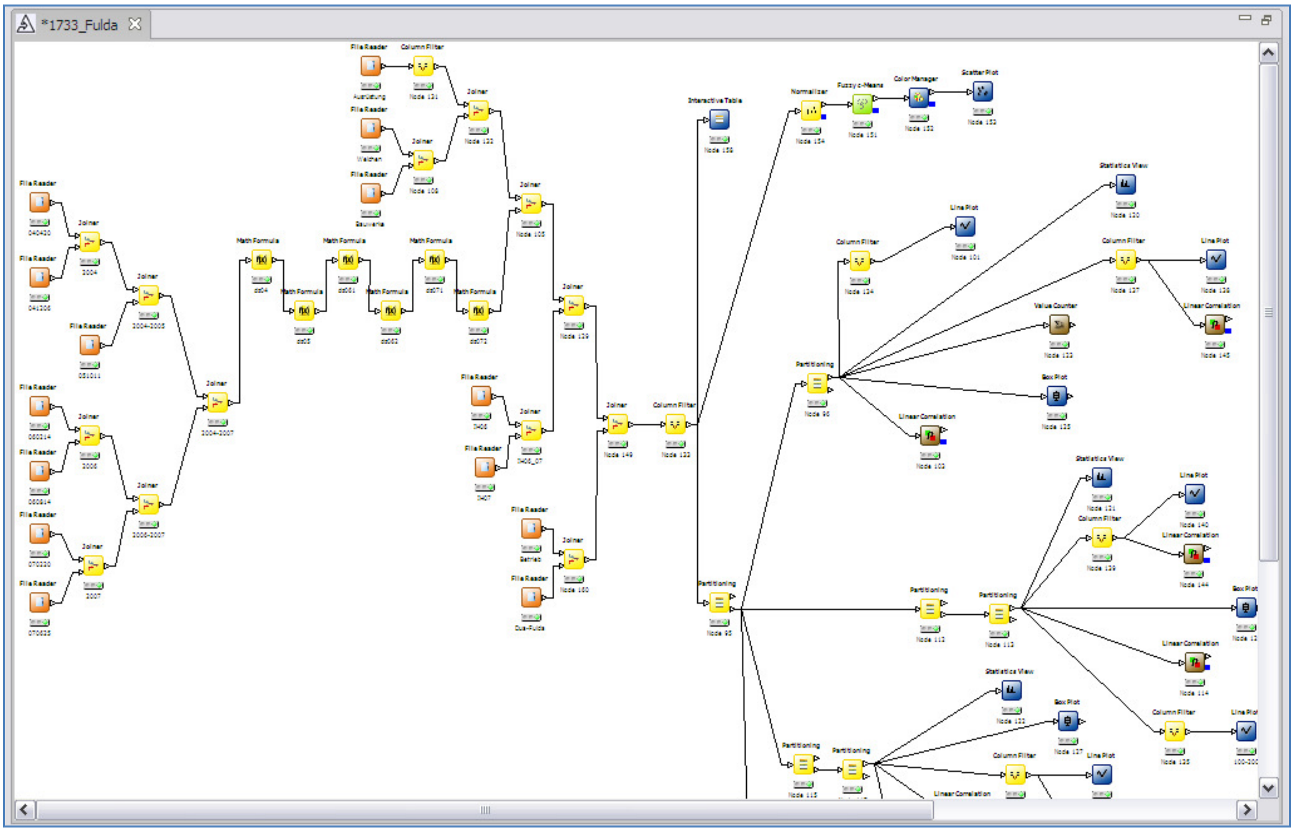


Figure 2: Cut-out of structure of data workflow for analysing track geometry faults

The different evaluations and views on the data of the DB Site No. 1 result, that there is ***no general correlation*** between failure, maintenance and costs and line routing data, track design and operational conditions.

The reason for this is that the behaviour of the different sections of the line not only depends on the **place** then on the **time** and **history**.

The consequences of these results are that the intended segmentation of the line due to line routing, track and operational parameters was not possible with the accuracy that is necessary for system or line optimisation.

Therefore a modification of the intended approach and introduction of another - the so called bottom-up approach - was necessary.

3.1.2 Bottom-up approach

Bottom-up-approach is a specification for the selected high speed line DB Site 1 and can be used for selection of cost driver sections of track line in case of no existing correlation between failures / maintenance data and line routing data / track data. (line routing data are data about track geometry elements like straight line, curve, transition curve, gradient, superelevation (cant) etc.).

In this approach detailed cost analysis of maintenance activities documented in DB SAP-R3 data base have been done parallel to the collection and evaluation of the whole available data for the track DB Site No.1. For the cost analysis only reliable maintenance data for the time period of the last 2 1/2 years (01/2005 – 06/2007) have been used. In this way, the identification of cost drivers - maintenance activities with the largest cost amounts - could be done independently of an existing correlation between maintenance data and line routing parameters.

The DB SAP-R3 system was not used for failures analysis, because failure types, their description and development in the data base were not documented in a form necessary for analysis of track construction.

The failures analysis was done for current status and current distribution of failures, which have been directly collected from infrastructure managers in net districts along the track.

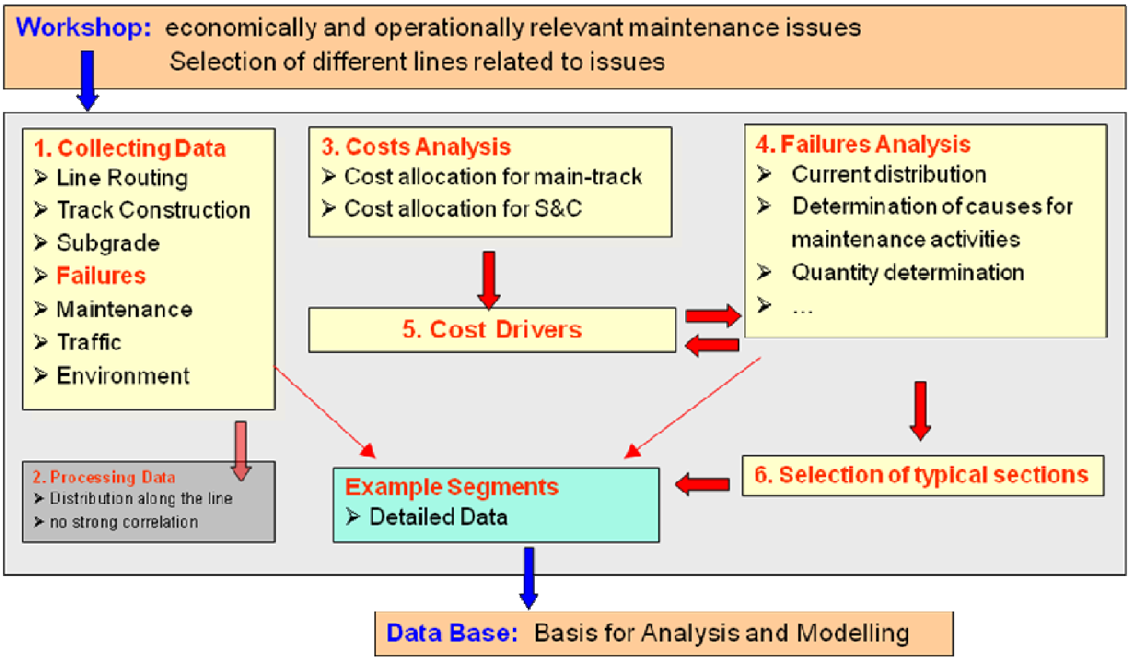


Figure 3: Schematic illustration of bottom-up approach

Failure of all elements and components of track have been collected and distributed along the line and in cooperation with infrastructure managers it has been determined which failures caused which maintenance activities in the past. The most important failures are identified by analysing the related maintenance cost during the last years.

It is assumed that the failure modes, which caused the most expensive maintenance activities (cost drivers) in the past, will also cause similar maintenance in future. Due to this fact, the track sections with such typical failure types at present time can be used as typical examples for cost driver sections of the analysed track line.

The selected sections typical for the fault modes causing cost drivers have to be described in detail in the same way as mentioned for the top-down approach. For the example sections, the same data details should be provided:

- line routing,
- track construction,
- subgrade data,
- data about current failures and failures history (as far as possible),
- maintenance activities data (with time, costs and history specification),
- traffic data and
- data about environment.

For the identified sections - typical for cost driving failures – the detailed data will be provided in the data base of InnoTrack for analysis and modelling.

3.2 Description of DB Track Site No.1

The Site No.1 is a high-speed railway track with a length of 327 km (double tracked, total length of both directions = 654 km).

This is a railway track line of the first category of DB, a part of the priority net, main line for passenger and freight transportation, with catenary (overhead contact line/wire), self-operated.

The track class is D4[1]; the track category P300[2] . The line is divided in 7 sectors (districts).

3.3 Structure of collected track data

The structure of the data collected for the track is shown in **Table 1**:

- 1. Track elements: line routing, track construction and subgrade
- 2. Track condition: failures and maintenance
- 3. Boundary condition: traffic, environment

This structure was also used in the segmentation.

Table 1: Data structure for analysis

1. Track elements

Line routing

Straight line	Curve		Transition curve
gradient	radius	< 300 m	clothoid
		300 - 700 m	sinusoid
		700 - 1500 m	cubic parabel
		1500 - 5000 m	Schramm
		> 5000 m	Bloss
	superelevation (cant)		Vienna curve

Track construction (main track, switches and crossings)

Rail	Sleeper	Pads	Ballast	S & C
type	type	type	type	type
profile	mean span	dyn.stiffness	thickness	parameters
inclination				
steel grade				

Subsoil

Protective layer	Earthwork	Construction	Transitions	Drainage
soil prot. layer	embankment	bridge	bridge/embankm.	ditches
frost prot. layer	cut	tunnel	tunnel/embankm.	deep drainage
			bridge/tunnel	
			level crosing	
Stiffness of subsoil				
soft: Ev2 < 80 MN/m²				
medium: Ev2 = 80-100 MN/m²				
stiff: Ev2 = 100-120 MN/m²				
very stiff: EV2 > 120 MN/m²				

2. Track condition

Failures

Track geometry	Rail surface	Switch	Failure of other track elements
vertical profile	headchecks	switch frog wear	
twist	squats	switch blade wear	
cant	belgrospis	headcheck	
alignment	rail corrugation	track geometrie	
gauge	side wear		
	weld		
			for Example: sludge spots ballast sinking etc.

Maintenance

Rail renewal
Rail grinding
Tamping of main track
- single failures, short sections
- long sections
Tamping of switches
Switch frog maintenace
Switch blade maintenace
Switch heating
Maintenance of drainage
Improvement of subsoil (embankment)
Position? Interval? Amount? Costs?
History of maintenance?

3. Boundary conditions (traffic, environment)

Traffic (Operation)	*Environment*
Load	**Temperatur Min/Max**
Speed	**Humidity / Rain**
Number of trains	**Depth of frost**
Types of trains	

3.4 Track elements

3.4.1 Line routing data

Line routing data are available in an Excel-File. The data collection is based on Access-tables from DB Net. A statistical evaluation of the line routing data for the DB track Site No. 1 is given in **Table 2**.

The routing data are divided in the three groups:

[1] track class with up to 22.5t axle load, see UIC leaflet 700

[2] P300 is one of seven different DB categories for a line, see DB standard

1. Elements of (horizontal) position

- straight line
  (total length: 154,46 km for direction 1; 154,96 km for direction 2
- curve
  (total length: 132,86 km for direction 1; 132,60 km for direction 2)
- transition curve:
  - clothoid
    (total length: 11,89 km for direction 1; 11,93 km for direction 2, see
  - S-shaped curve
  - Bloss-curve

2. Gradients

- linear
  - without gradient,
  - increasing (max 13,5 ‰) or
  - decreasing (falling) (max 12,5 ‰)
- quadratic parable

3. Superelevation (cant) elements

- constant superelevation (cant)
- straight line ramp
- S-shaped ramp
- Bloss-ramp

Table 2: Statistic of line routing, DB Site 1, direction 1

Elements of (horizontal) position	Type	Number of segments	Total length of segments [km]	Rate [%]	Min segment length [m]	Max segment length [m]	Min radius [m]	Max radius [m]
	Direction 1							
Straigt line	0	130	154,46	47,03	41,60	7392,87		
Curve	1	153	132,86	40,45	24,80	4763,88	200,00	37000,00
thereof								
R<300m		1						
300=>R<700m		12						
700=>R<1500m		26						
1500=>R<5000m		23						
R=>5000m		91						
Transition curve Clothoid	2	200	39,05	11,89	20,07	318,21	527,35	20004,70
Transition curve S-shaped curve	3	6	0,50	0,15	80,00	90,12	2800,00	10000,00
Transition curve Bloss-curve	4	2	0,38	0,12	191,80	191,80	4504,70	4504,70
Straighten line bend at the end +200	5	3	1,21	0,37	29,22	881,23	199,97	200,06
Total:		647	328,46	100,00				

Gradients	Type	Number of segments	Total length of segments [km]	Rate [%]	Min segment length [m]	Max segment length [m]	Min gradient [‰]	Max gradient [‰]
	Direction 1							
Straight line	0	290	293,89	89,33	20,77	8552,01		
thereof								
without gradient		20	9,35	2,84	31,90	7948,35		
increasing (sign +)		153	145,84	44,33	20,77	7885,95	0,066	13,500
decreasing (sign -)		117	138,70	42,16	24,41	8552,01	-0,013	-12,506
Quadratic parable	1	226	35,11	10,67	19,96	1250,07	beginning/end gradient>0 0,000	-12,501 13,500
Total:		516	329,00	100,00				

Elements of superelevation (cant)	Type	Number of segments	Total length of segments [km]	Rate [%]	Min segment length [m]	Max segment length [m]	Min cant [cm]	Max cant [cm]
	Direction 1							
Constant superelevation (cant)	0	208	285,94	87,82	24,80	7392,87	(0) 2,00	14,50
thereof								
without superelevation (cant)		104	162,49	49,90	96,25	7392,87	0,00	0,00
straight line ramp	2	199	38,94	11,96	20,00	318,21	beginning / end cant > 0 2,00	14,50
S-shaped ramp	3	4	0,34	0,10	80,00	90,12	beginning / end cant > 0 4,00	4,50
Bloss-ramp	4	2	0,38	0,12	191,80	191,80	beginning / end cant > 0 8,50	8,50
Total:		**413**	**325,60**	**100,00**				

3.4.2 Track construction data

Track construction data is based on DB SAP R/3-Tool-Evaluation of infrastructure for the site No.1 from DB Net. This evaluation contains data for the track, switches and crossings, bridges, tunnels, earthwork constructions and supporting structures of the whole track line including all railway stations along the line.

The standard elements of the track construction of the site No.1 are:

- **Rail: UIC 60 / steel grade 880**

  otherwise existing: 49 / 690 and 54 / 880 (noteworthy) and marginal LF / 680
- **Sleeper: concrete sleeper B70 W with spacing 60 cm**

  otherwise existing: a lot of timber sleepers (railway stations), some segments with B58 few segments with B75, B90, B93 and B10, and partially few segments with steel sleepers and slab track
- **Rail fastening: type W14, with wedge clamps Skl14**
- **Pads: Zw 700 with medium dynamic Stiffness (100 - 400 kN/mm)**

  otherwise existing: Zw 900 (some bridges) and only sporadic Zw 687a

  (Change of non-elastic pads Zw 687a with elastic pads Zw 700 / Zw 900 in the time period 1992 – 2003)
- **Ballast: standard thickness, 35 cm, grain size between 22,4 mm and 63,0 mm according DB standard, E-modulus 200 MN/m²**

There are 458 switches and crossings on the track line of the DB Site No.1. According to radius S&C can be divided in the following groups:

Table 3: number and distribution of switches and crossings

Radius curve S&C	number
Others (<190 and radii narrow gauge S&C)	1
190 (incl. sym. wye turnout 215)	34
300	56
500	44
760	34
1200	206
2500	79
4800/2450	2
7000 / 6000	2
result	**458**

The construction types of S&C on the DB track site 1 are:

- simply switch left,
- simply switch right,
- simply switch symmetric,
- simply crossing switch and
- double crossing switch and crossing.

3.4.3 Subgrade data

Subgrade for the track construction of the DB Site No.1 was built-up 20 years ago. Outside of engineering constructions, the subgrade is strong compacted earthwork (soil) and has a single protective layer of 30 cm thickness. The soil subgrade can be described as very stiff, because its modulus of static deformation (Ev2) is larger than 120 MN/m².

There are a lot of **constructions** – bridges and tunnels (see **Table 4**) - along the line and therefore there exist a large number of transition-sections (bridge-earthwork, tunnel-earthwork, bridge-tunnel). Transition - sections are exposed to higher dynamical stresses and need more maintenance-work.

The condition of the **drainage constructions** for the DB track site 1 can be compared with a new one. They are partially oversized and still don't need noteworthy maintenance.

Constructions: tunnels, bridges and expansion joints

A large part of the track line is situated in tunnels. There are 64 tunnels on the line, with total length of 123 km (38 % of total track length, see Table 4).

The total amount of bridges is 147. 66 bridges have a length over 50 m (long bridges) and 81 bridges are shorter than 50 m. The total length of all bridges is 31 km (10% of total track length). Approximately one half of all long bridges have been equipped with under ballast mats (UBMs) (Table 4).

There are 13 bridges with expansion joints:

- 5 bridges with 1 expansion joint per direction (total 5x1x2=10 joints)
- 5 bridges with 2 expansion joints per direction (total 5x2x2=20 joints)
- 3 bridges with 3 expansion joints per direction (total 3x3x2=18 joints)

Total number of expansion joints on the track Site 1 for both directions: 48 joints

Table 4: Overview tunnels and bridges

Constructions	*Amount*	*Length*
Tunnels	64	∑ 123 km (38 % of total track length)
Bridges with length ≥ 50 m	66	∑ 30.139 m
Bridges with length < 50 m	81	∑ 876 m
	∑147 bridges	**∑ 31.015 m (10% of total track length)**
Bridges with under-ballast mats		
Direction 1	22	∑ 12.765 m
Direction 2	30	∑ 17.249 m
	∑ 52 bridges	**∑ 30.014 m**

3.5 Track condition - failures & faults

Failure categorisation has been done according to table of fault categorisation from Innotrack / SP1 / WP 1.4; the failure table here has been extended by some typical failures, which have been found on the DB track Site 1 (see **Table 5**).

Failures of track construction can be detected through different inspections and measurements, which have to be done in regulated intervals.

DB has a specialised system for collection, presentation and evaluation of results of inspections and measurements (IIS: Intelligent Inspection System). The IIS-diagrams and tables with overstepping of limiting values are the basis for infrastructure managers to make decisions for maintenance works.

Table 5: Failure catalogue in general

Rail	Fastening	Pads	Sleepers
Short-wavelenght corrugation	Broken wedge clamp	Worn	Bending failure
Belgrospis	Loose	Split	Shear failure
Headchecks / RCF	Missing	Disintegrated	Bearing failure
Squats		increased Stiffness	Attrition
Long-wavelenght corrugation			Reinforcement corrosion
Side wear			
Fracture			
Other			

Ballast	Subgrade	Drainage	Switches / Crossings
White spots	Diff. settlements	Blockage	Rail
Compacted crumbled ballast	Loss of bearing capacity	Low flow capacity	Fastenings, Pads and Sleepers
Different settlements	Sludge spots		Ballast
Loss of stability			Switch frog
Reduced drainage capability			Switch blade
			Failure of other elements

3.5.1 Failures of track geometry

The geometry of the track Site No.1 has been measured by the track recording coach every 3 months. The most important measurement parameters are:

- vertical profile of left and right rail, z1 and z2 (longitudinal level)
- horizontal profile of left and right rail, y1 and y2 (lateral level or alignment)
- track gauge, sp
- superelevation (cant), gh
- curvature (1/R), kr
- twist, vw

All measured parameters (total number 28) are functions of the place [km] and could be plotted and compared graphically (in a raster of 1m) or evaluated numerically. The description of all parameters of track geometry measurements is given in **Table 6**.

For all selected example sections DB will provide two data sets from track geometry measurements with the eight most important parameters (described above): the first data set is from 2006 and the second from 2007.

DB can provide more data sets and additional parameters, if necessary for simulation.

Table 6 Description of track geometry measurement parameters

Column No.	Signal	Unit	Parameter	Track recording coach	Comment
1	km	[0.001 km]	Position		
2	E_S0(_z2_hp50_)	[0 .1 mm]	vertical profile of right rail or longitudinal level of right rail	OMWE/RAILab	laser measurement *(at present no limit values for evaluation)*
3	E_S0(_z1_hp50_)	[.1 mm]	vertical profile of left rail or longitudinal level of left rail	OMWE/RLab	laser measurement *(at present no limit values for evaluation)*
4	E_S0(_sp_)	[.01 mm]	track gauge	OMWE/RAILab	
5	E_S0(_gh_)	[.01 mm]	superelevation (cant)	OMWE/RAILab	
6	E_S0(_y1_hp50_)	[.1 mm]	lateral level (alignment) of left rail	OMWE/RAILab	laser measurement *(at present no limit values for evaluation)*
7	E_S0(_y2_hp50_)	[.1 mm]	lateral level (alignment) of right rail	OMWE/RAILab	laser measurement *(at present no limit values for evaluation)*
8	E_S0(_kr_)	[.000001 m-1]	curvature [1/R]	OMWE/RAILab	
9	E_S0(_vi_)	[km/h]	current speed	OMWE/RAILab	
10	E_S0(_sp_ohne_)	[.01 mm]	? unknown		
11	G_S0(_z2_c_)	[.01 mm]	longitudinal level of right rail	GMTZ	chord measurement *(limits for evaluation are defined in the guide lines)*
12	G_S0(_z1_c_)	[.01 mm]	longitudinal level of left rail	GMTZ	chord measurement *(limits for evaluation are defined in the guide lines)*
13	G_S0(_y1_c_)	[.01 mm]	alignment of left rail	GMTZ	chord measurement *(limits for evaluation are defined in the guide lines)*
14	G_S0(_y2_c_)	[.01 mm]	alignment of right rail	GMTZ	chord measurement *(limits for evaluation are defined in the guide lines)*
15	E_S0(_gh_hp_)	[.01 mm]	failure of superelevation	OMWE/RAILab	high-pass filtered, long wave signals not included
16	E_S0(_vw_ore_srlim_)	[.00001 1]	twist as % of SRlim-value	OMWE/RAILab	
17	E_S0(_vw_ore_sr100_)	[.00001 1]	twist as % of SR100-value	OMWE/RAILab	
18	E_S0(_vw_basis_ber_)	[.00001 1]	twist as funktion of measure basis	OMWE/RAILab	twist calculation for 13 different measure basis (1,5m to 21m)
19	E_S0(_uf_)	[.01 mm]	cant deficiency	OMWE/RAILab	
20	__S0(km11)	[100000 mm]	position coordinate		intern use for determination of track-km
21	__S0(km21)	[655360 mm]	position coordinate		intern use for determination of track-km
22	__S0(km22)	[10 mm]	position coordinate		intern use for determination of track-km
23	__S0(vzul)	[km/h]	permitted speed		
24	__S0(zeit)	[1]	time		
25	__S0(sta1)	[1]	? unknown		
26	__S0(sta2)	[1]	? unknown		
27	__S0(inf1)	[1]	? unknown information about construction		
28	__S0(inf2)	[1]	information about construction type		Informations about construction type and position: tunnels, briges, swiches, crossings, stations

Legend:
hp50 = high-pass filtered up to wave lenght of 50m
E = OMW**E**
G = **G**MTZ
S0 = original signal (processing step 0)

3.5.2 Rail failures

Characteristic rail failures on the DB track site 1 are short-wavelength-corrugation, belgrospis and head checks.

Rail failures can be detected through visual inspections, rail surface measurements or ultra-sonic measurements of rail.

Categorisation of rail damage degree should be done with selective detailed ultra-sonic measurements of rail or eddy current measurements (in case of head checks).

Rail breakage data base

On the base of DB SAP-R3-System it is possible to query rail breakages and large rail failures, which need repair immediately or within the next six weeks. This query can be done automatically and is designed as an own data base called rail breakage data base.

The rail breakage data base contains failure reports (messages) about rail breakages and rail failures of category No.1 (by ultra-sonic detected rail failures with overstepping evaluation limits or rail failures in an extraordinary position, according DB guide line 821.2007).

Data state for the DB track site No.1 in the rail breakage data base was:

- In year 2006: 1 rail breakage and 51 rail failures of category 1 (thereof 21 in switches)
- In the first half of year 2007: no rail breakage but 23 rail failures of category 1 (thereof 10 in switches)

Short-wavelength-corrugation

Short-wavelength-corrugation occurs in line sections with high speed, independent of line routing elements: in straight line as well as in curves with large radius. In high-speed sections short wavelength corrugation are situated only in curves with large radius. In tunnels no rail corrugation was found.

The development of this rail failure type is not complete understood. One of the reasons could be use of transmission-slip control, especially for locomotives.

Sections with short-wavelength-corrugation can be identified and measured by rail surface measurements. These measurements are laser long chord measurements and have been done with machine SM 775 by company Speno once a year for all DB high-speed lines and lines with high traffic load. The results are lists with km-specification of sections with short-wave-corrugation, which have a wave-amplitude larger then 2/100 mm (two hundredth of 1 mm). The lists are saved in the IIS-system (IIS: Intelligent Inspection System).

Rail surface measurements of the track site No.1 for the analysis within the project InnoTrack are available for the time period 2001-2007.

Belgrospi

Belgrospis are special rail failures of high-speed lines (see **Figure 4**). Belgrospis occur mainly in connection with short-wave-corrugation on places with corrugation wave depth > 3/100 mm, as consequence of higher stresses on the crests of waves. They develop as indentations and cracks on crests of waves and can be found as single failures or failure groups (nests).

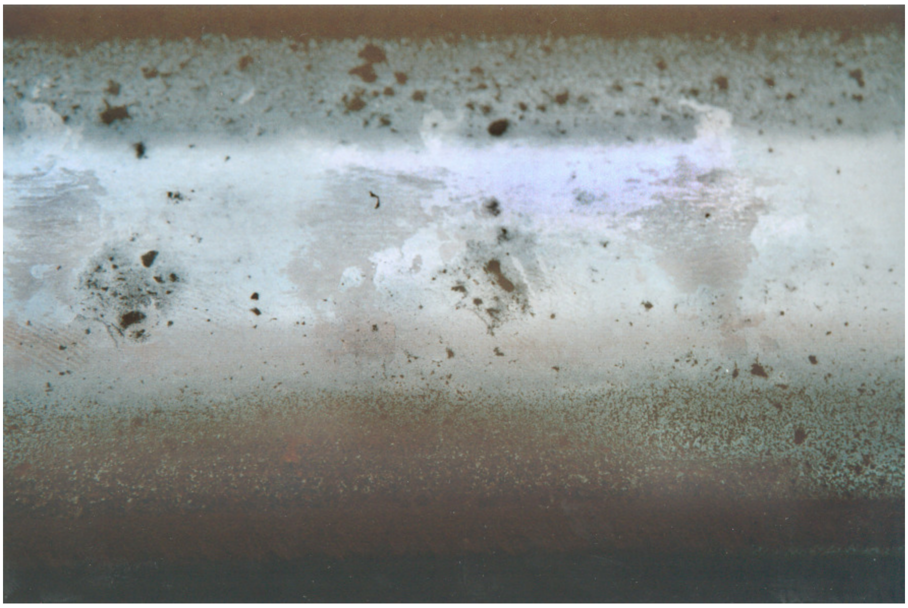


Figure 4: Belgrospis of category 3; source DB regulation 821.2007A02

This type of rail failures occurs only in sections with line speed v ≥ 200 km/h and only in areas outside of tunnels.

On the DB track site 1, rail failures Belgrospis appeared for the first time ca. 10 years after opening the line. At present time they are the most problematical rail failure types on this track, because if Belgrospis are detected the rail has to be removed.

Head Check

On the DB track site 1 head checks can be found in sections with lower traffic speed (max v = 160 - 170 km/h) - in curves with relative small radius and in switches.

Head checks develop as consequence of rolling contact fatigue and occur as surface cracks on the running surface of the rail (see **Figure 5**). This type of failure appears primarily in curves, but they can be found also on straight line sections, if the track geometry is in a poor condition.

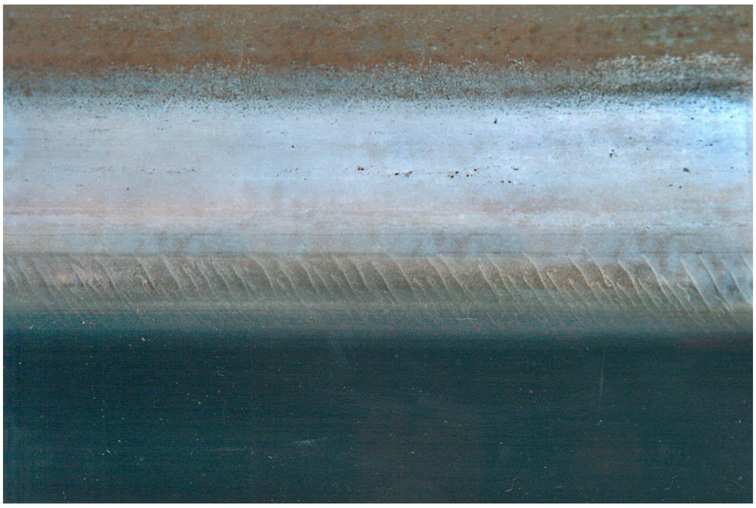


Figure 5: Head Check of category 3; source DB regulation 821.2007A02

One example section with head checks on a straight line, which has been found on the second DB track site, will be described in detail for the InnoTrack data base.

Head checks on the high-speed DB track site 1 are not very frequent and at this line no cost driver.

There is only one longer section (between km 133 und km 150) with narrow curves and maximal allowed speed of v = 170 km/h with a large number of head checks along the line. This part of the track does not belong to the high-speed sector.

In general the head checks can be found more often in narrow curves. But depending on the track geometry faults and the vehicle dynamics (especially for high speeds) head checks are detected also on straight lines.

For example Figure 6 shows a straight track section where strong head checks were detected.

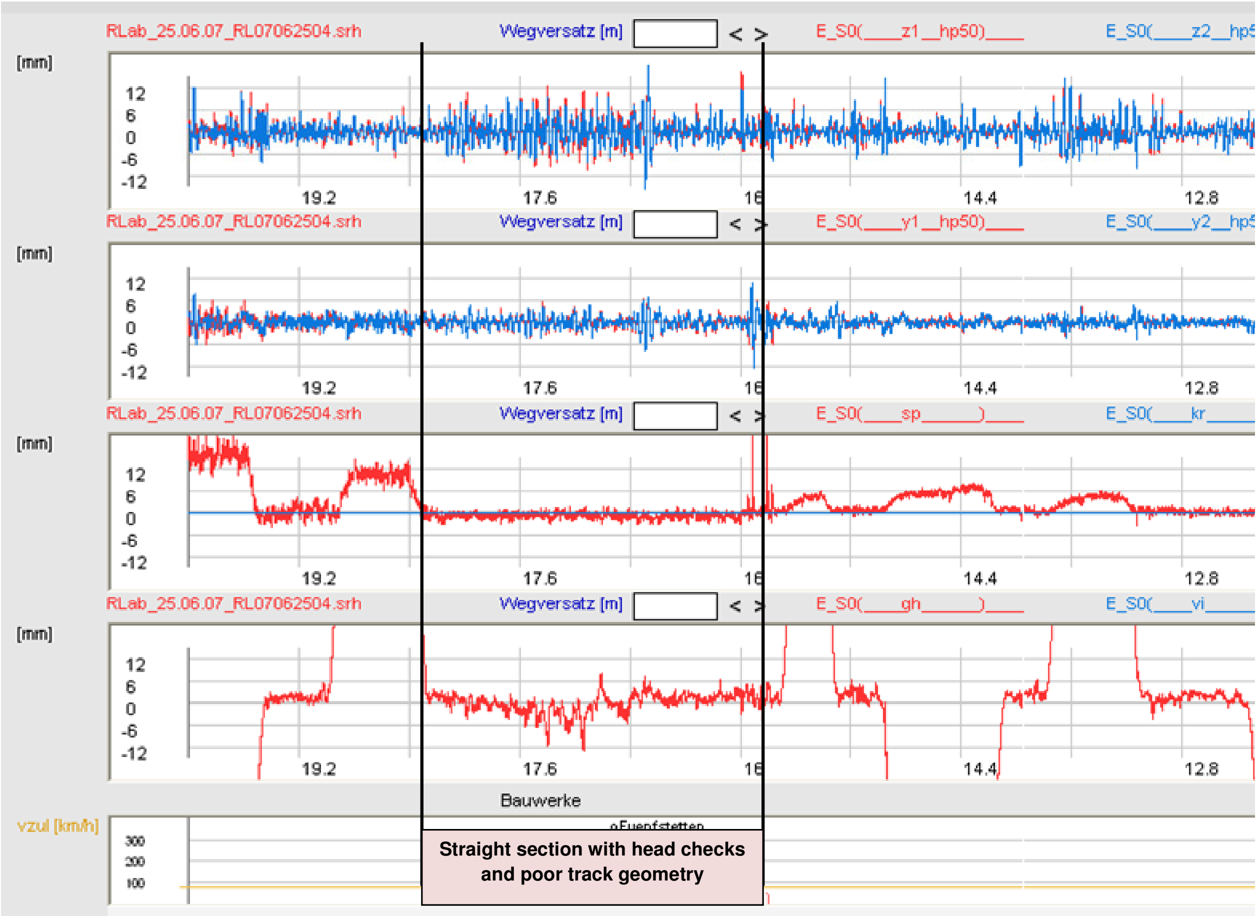


Figure 6: Track section with track geometry causing head checks on straight section

Other rail failures

Lateral wearing and vertical wearing-down of rail are minimal on the DB track site 1 and don't cause significant problems. All other rail failures occur on the DB site 1 only in small amount. They are no maintenance cost drivers.

3.5.3 Switch failures

Most of the rail failures in switch sections are head checks. The average life cycle of switch frog and switch blade on track site No. 1 is about 15 to 20 years. Due to the fact that the track construction is between 18 and 20 years old, a large number of switches need renewal of these elements in the next years.

Track geometry faults occur more frequently in switch sections than in sections of main track. The average time interval for correction of track geometry through ballast tamping and rail grinding is about two years.

Failures in switches with bifurcation of the track line are occurring more often than for other S&Cs.

3.5.4 Failures of other track components

Ballast

At the beginning of operation of the track site, one section (about 40 km long) has been used as testing track section for high speed train traffic. As consequence of heavy duty (high speed, high dynamic loads, frequently tamping and dynamic stabilisation of ballast) the ballast under the sleeper in this track section has been badly damaged (crumbled). The ballast layer has been transformed into strong compacted mineral soil layer. This effect can be found outside of the test section only around expansion joints of bridges.

The thickness of the ballast layer in the high-speed test section was measured in 1997. As result an average thickness between 27 cm and 30 cm was recorded.

On bridges and in transition areas between engineering constructions and subsoil so called **"white spots"** in the ballast layer can be found. The main reasons for this failure mode, which causes frequent tamping of the transition zones, are:

- longitudinal displacements of the bridge end due to loading and temperature and
- high dynamical stresses in the ballast due to the huge variation of subgrade stiffness in the transition zone.

To reduce these effects, 52 bridges have been upgraded with under ballast mats (UBM) from 1997 to 1999. On one bridge the track was rebuilt using sleepers with under sleeper pads (USP). As a result of the upgrades, the bridges with UBMs and USPs show a more constant quality of track geometry and a reduction of maintenance in the last years. But at the end of the rebuilt track sections, which are on the subsoil, higher vertical failures can be observed in the track geometry.

White spots in ballast can occur also in case of single geometry faults of rail – for example as a consequence of improperly rail welding. The welding area that is shown in ***Figure 7*** causes strong local ballast settlement and lead to white spots in ballast. Also the straightening area causes local ballast settlement that requires additional local maintenance. The requirements regarding the geometric quality of welding (e.g. straightness of the rail) strongly depend on the vehicle and the speed.

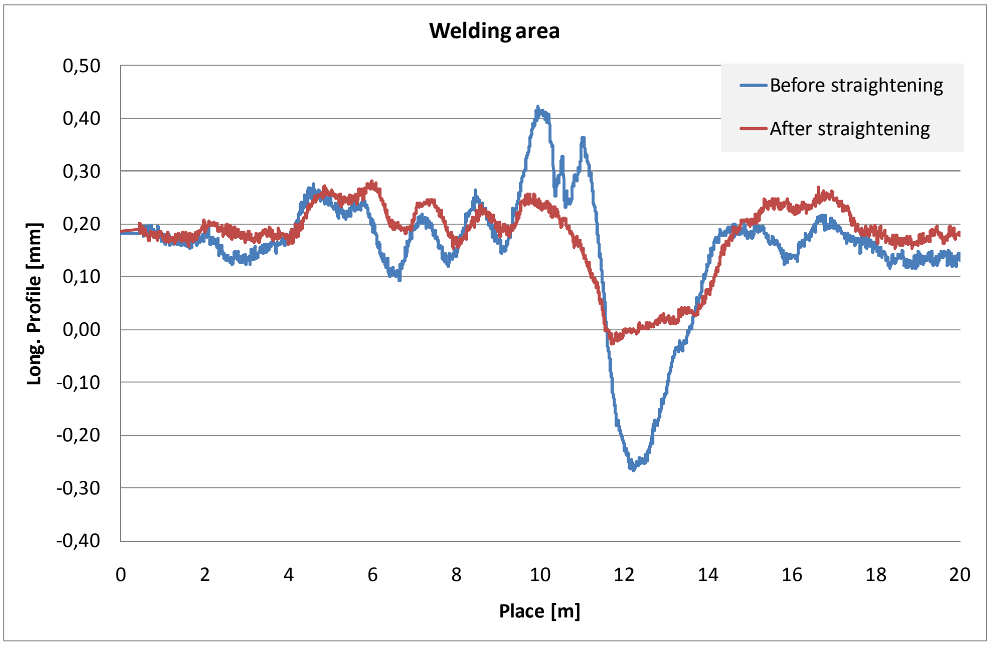


Figure 7: Welding area causing strong ballast settlement

The mechanism of white spot development in ballast layer is the same as in the case of transition areas: high dynamic stresses due to rail geometry fault have been transferred over sleeper into ballast and cause abrasion of ballast grain. During the time, ballast settlement increases and causes further track geometry failures.

Because of large number of engineering construction on the DB track site 1 and thereby large number of transition areas, the failure type "white spots" of ballast is very frequent on the analysed track.

Sleepers

There are three longer sections on the track site with sleepers in a defective condition.

The first of them is situated in a transfer line (station) at the end of the testing track section for high speed train traffic. It is about 2 km long and has sleepers with crack formations. The infrastructure manager of this district is of the opinion, that the reason for the damaged sleepers is the hard ballast layer, consisting of strong compacted crumbled ballast grains.

The second section with 800 m length is also situated in a transfer line (station). In direction one approximately 200 sleepers with cracks and in direction 2 approximately 150 damaged sleepers were detected The sleeper cracks occurred for 4 years and the reason could be possibly pads renewal – change of “non-elastic” pads Zw 687 to “elastic” pads Zw 700 (with medium dynamical stiffness 100 - 400 kN/mm). In the same section also “white spots” occur frequently in the ballast. The direction two of the same section is selected as an example section for white spots in ballast (see Chapter 3.9).

The third section with damaged sleepers is an 8 km long plain line section between two stations. There are a lot of sleepers with cracks in area of bottom reinforcement bars. The reasons for the cracks are unknown.

Expansion joints

The average life cycle of expansion joints on bridges on the DB track site 1 is about 20 years. Due to the fact that the track construction is between 18 and 20 years old, a large number of expansion joints needs renewal in the next years.

Track geometry faults and white spots in ballast occur very frequently in areas of expansion joints. These areas need correction of track geometry through ballast tamping at least once a year.

Overview

An overview of all documented failures of track components, which occur on the analysed DB site is given in **Table 7**.

Table 7: Failure catalogue for the DB track site 1 (coloured failures occur on the analysed track)

Rail	Fastening	Pads	Sleepers
Short-wavelenght corrugation	Broken wedge clamp	Worn	Bending failure
Belgrospis	Loose	Split	Shear failure
Headchecks / RCF	Missing	Disintegrated	Bearing failure
Squats		increased Stiffness	Attrition
Long-wavelenght corrugation			Reinforcement corrosion
Side wear			
Fracture			
Other			

Ballast	Subgrade	Drainage	Switches / Crossings
White spots	Diff. Settlements (Transitions)	Blockage	Rail
Compacted crumbled ballast	Loss of bearing capacity	Low flow capacity	Fastenings, Pads and Sleepers
Different settlements	Sludge spots		Ballast
Loss of stability			Switch frog
Reduced drainage capability			Switch blade
			Failure of other elements

3.6 Cost analysis - identification of cost drivers

As mentioned in a previous chapter the Basis for the cost analysis was the DB SAP-R/3 database for maintenance activities of track construction of the DB site No. 1 for the time period between 01/2005 and 06/2007. Maintenance activities (MA) have been evaluated separately for main track as well as for switches and crossings (S&C). The main focus of this report is the cost analysis of the main track.

To achieve a general conspectus of the costs, the activities have been divided in five groups:

- Ballast
- Rail
- Renewal and Reconstruction
- Other MA's of track construction
- Inspection

The category "other MA's" contains items like "miscellaneous (ballast)" and "repair".

The category "inspection" contains different inspection procedures, like "rail inspection", "acoustic discharge measurement" etc. (see Figure 8).

MTN-acronym	explanation	component	Cost Drivers
2X	miscelaneous	other MA	no cost driver
3B	crossing works	other MA	no cost driver
3D	tamping (work over) rail track	Ballast	tamping
3E	tamping (work over) swiches	Ballast	no cost driver
3F	rail renewal	Rail	rail renewal
3G	ironmongery conditioning	other MA	no cost driver
3H	sleeper reconstruction	Renewal and Reconstruction	no cost driver
3I	small repair	other MA	no cost driver
3J	ballast renewal	Ballast	no cost driver
3K	ballast reconstruction	Ballast	no cost driver
3L	remedy of sludge spots	Ballast	no cost driver
3O	renewal of large elements	Renewal and Reconstruction	new building and reconstruction of track
3Q	switch reconstruction	Switch	no cost driver
3U	new building and reconstruction of rail track	Renewal and Reconstruction	new building and reconstruction of track
3V	new building and reconstruction of swiches	Renewal and Reconstruction	no cost driver
3X	miscellaneous (ballast)	other MA	no cost driver
4A	stress equalisation	Rail	no cost driver
4I	construction of insulated rail joint	Rail	no cost driver
4S	grinding	Rail	no cost driver
4T	build-up welding	Rail	build-up welding
4V	welding of rail joint	Rail	no cost driver
4X	miscellaneous (rail)	other MA	no cost driver
5Y	switch heating works NEWHZ	Switch	no cost driver
5Z	conjunction work track superstructure	other MA	no cost driver
AKT	building in general	Renewal and Reconstruction	new building and reconstruction of track
BZL	supervision	other MA	no cost driver
D07	winter service	other MA	no cost driver
D13	interruption declaration	other MA	no cost driver
ENT	fault elemination	other MA	no cost driver
GAS	build-up welding (track) / m line	Rail	build-up welding
GBA	complete ballast replacement (rail track)	Ballast	no cost driver
GBR	ballast cleaning (rail track)	Ballast	no cost driver
GDZ	machined tamping (work over) rail track + additional works	Ballast	tamping
GGT	GI Renewal of large elements	Renewal and Reconstruction	no cost driver
GPL	subgrade improvement (rail track / m line)	subgrade improvement	no cost driver
GSI	rail renewal (track) / m line	Rail	rail renewal
GSS	machined grinding (track) / m line	Rail	machined grinding
GSW	sleeper reconstruction (rail track /m line)	Renewal and Reconstruction	no cost driver
GUK	Reconstruction/Renewal (AKZ 2 ?) / m line	Renewal and Reconstruction	no cost driver
I70	Rail inspection	inspection	inspection
I72	Rail inspection ride	inspection	inspection
I75	rail geometry measurement	inspection	inspection
I76	acoustic discharge measurement	inspection	inspection
I77	acoustic discharge measurement	inspection	inspection
I79	rail surface measurement	inspection	inspection
I86	measurement of track dynamics	inspection	inspection
I87	inspection of expansion joints	inspection	inspection
IBR	bridge repair	other MA	no cost driver
IEB	EBA inspections	inspection	inspection
INL	inspection temporary fish-plating	inspection	inspection
INS	repair	other MA	repair
ISE	miscellaneous inspection	inspection	inspection
ISI	extra inspection	inspection	inspection
ITU	tunnel repair	other MA	no cost driver
LWE	maintanance of el. components SC/GSP?	Switch	no cost driver
LWM	maintanance of mech. components SC	Switch	no cost driver
M01	rail track tamping machines	Ballast	no cost driver
M02	swtich tamping machines	Ballast	no cost driver
M03	reconstruction machines	Ballast	no cost driver
M04	ballast cleaning machines	Ballast	no cost driver
M05	ballast leveling machines	Ballast	no cost driver
M07	locomotive transporting service	Ballast	tamping
M10	machine from external supplier	Ballast	tamping
M11	machine staff	Ballast	tamping
M12	measurment service	Ballast	tamping
M14	tamping machine for correction of single failure of track geometry	Ballast	no cost driver
OE1	planning backfitting track	other MA	no cost driver
OE2	planning backfitting switch	other MA	no cost driver
OE3	backfitting track	other MA	no cost driver
OE4	backfitting switch	other MA	no cost driver
OE5	planning backfitting track	other MA	no cost driver
OE6	planning backfitting switch	other MA	no cost driver
OLD	mast refurbishment	other MA	no cost driver
OLI	repair OI	other MA	no cost driver
PKI	small maintenance	other MA	no cost driver
PLA	activatable planned activity	other MA	no cost driver
SP	special troop Renewal of large elements	Renewal and Reconstruction	no cost driver
TEW	low lined drainage (track, SC / m drainage)	low lined drainage	no cost driver
TK	inspection telecomm. System	other MA	no cost driver
VCH	cemical vegetation control	other MA	no cost driver
VGD	landscape conservation stage D	other MA	no cost driver
VGI	landscape conservation stage I	other MA	no cost driver
VGP	landscape conservation stage P	other MA	no cost driver

Figure 8: Overview of maintenance measures (costs) and their categorisation according to components and according to cost drivers

The Figure 9 shows the costs distribution of all incurred costs for the DB track site No. 1 (listed in Figure 8) for the defined five cost categories.

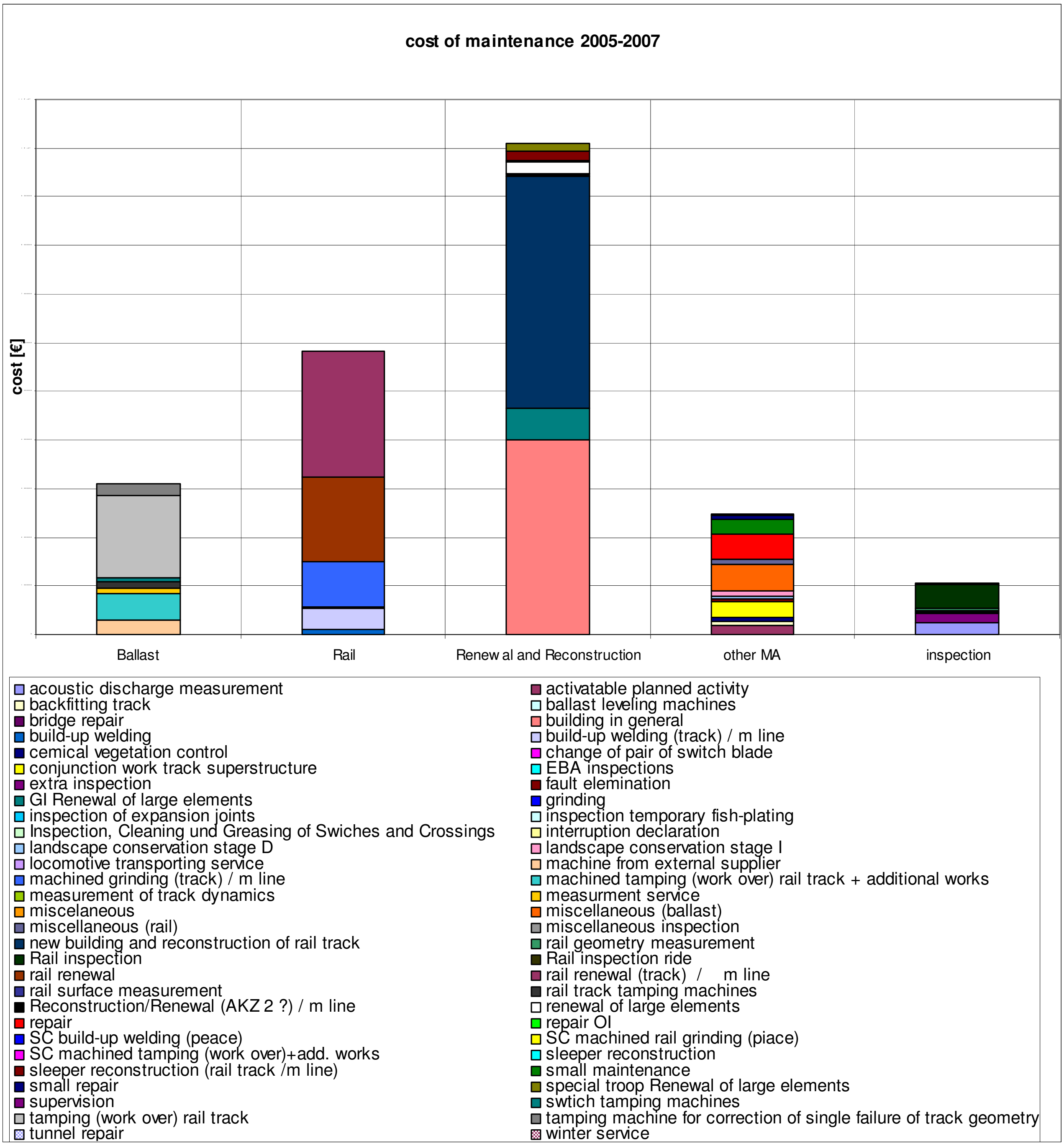


Figure 9: Costs distribution of all incurred costs for the DB track site No. 1

The higher amounts of all incurred MA costs (inspection exclusive) have been selected out and presented as cost drivers in Figure 10.

It is obvious that the main costs have been generated by renewal and reconstruction, followed by rail maintenance costs.

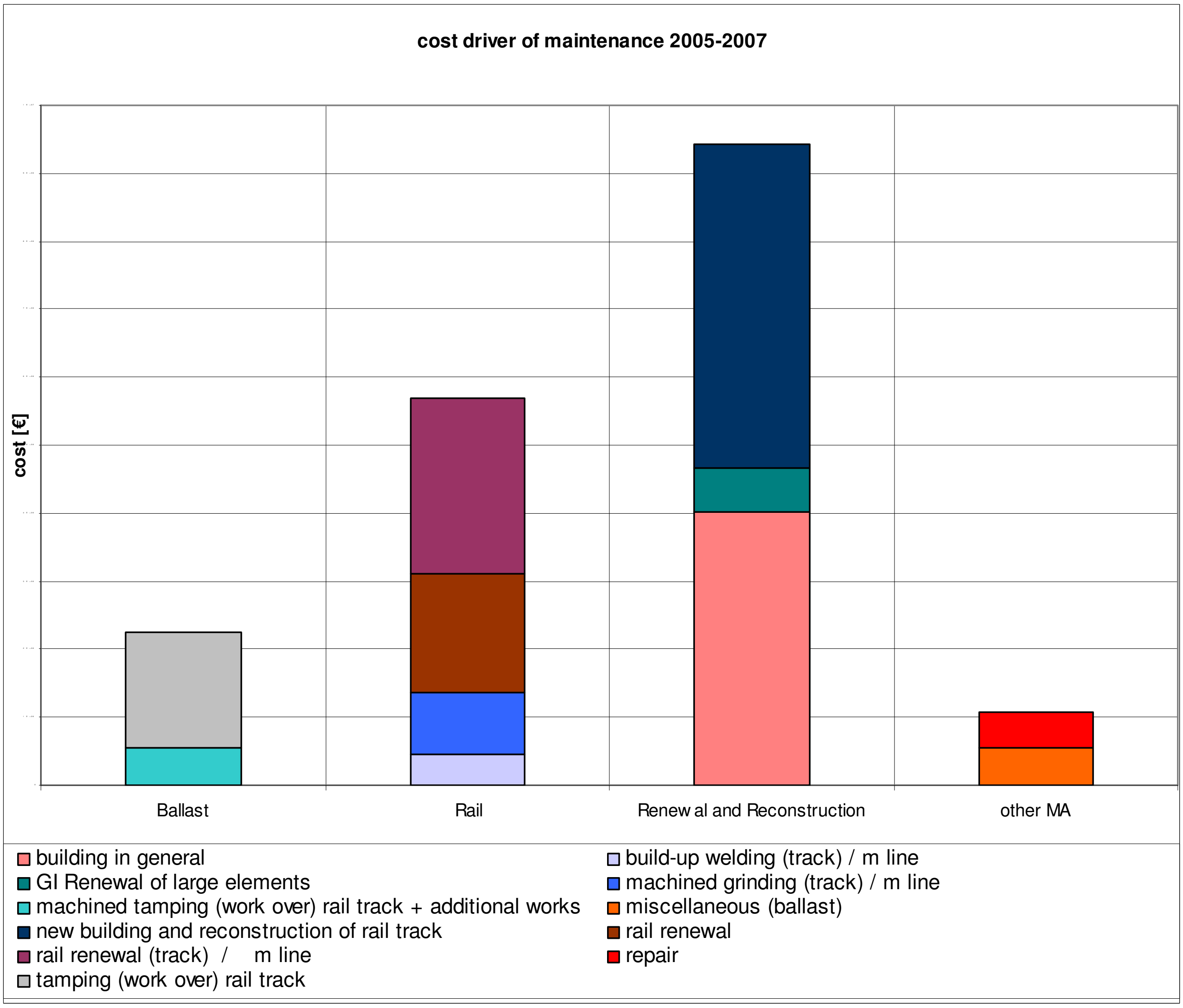


Figure 10: MA costs drivers of DB track site No. 1

In the next step the cost drivers were statistically quantified in working categories. These working categories in order of their percentage of total costs are:

- New building and reconstruction of track (41 %)
- Rail renewal (19 %)
- All other costs (15 %)
- Tamping (12 %)
- Inspection (5 %)
- Machined grinding (4 %)
- Repair (2 %)
- Build-up welding (2 %)

The cost distribution in relation to total costs within the analysed period is shown in Figure 11.

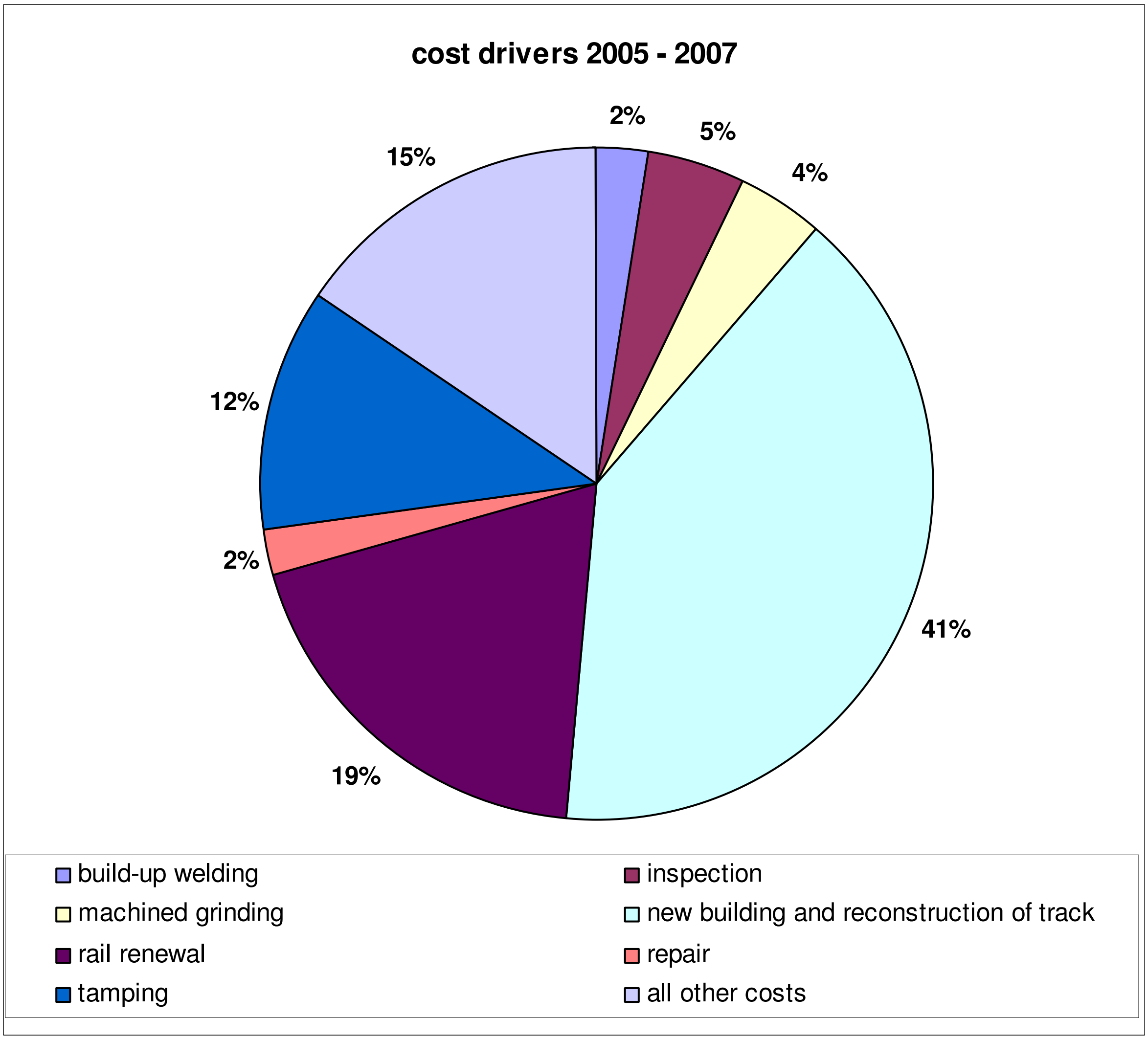


Figure 11: Cost driver distribution in relation to total costs

Figure 12 shows the cost distribution of the defined working categories without the category “all other costs”. Within these categories nearly half of the costs were caused by new building and reconstruction of track. Nearly a quarter of the costs were invested for rail renewal followed with 14 % for tamping. The rest of the cots were between 3 % and 6 %.

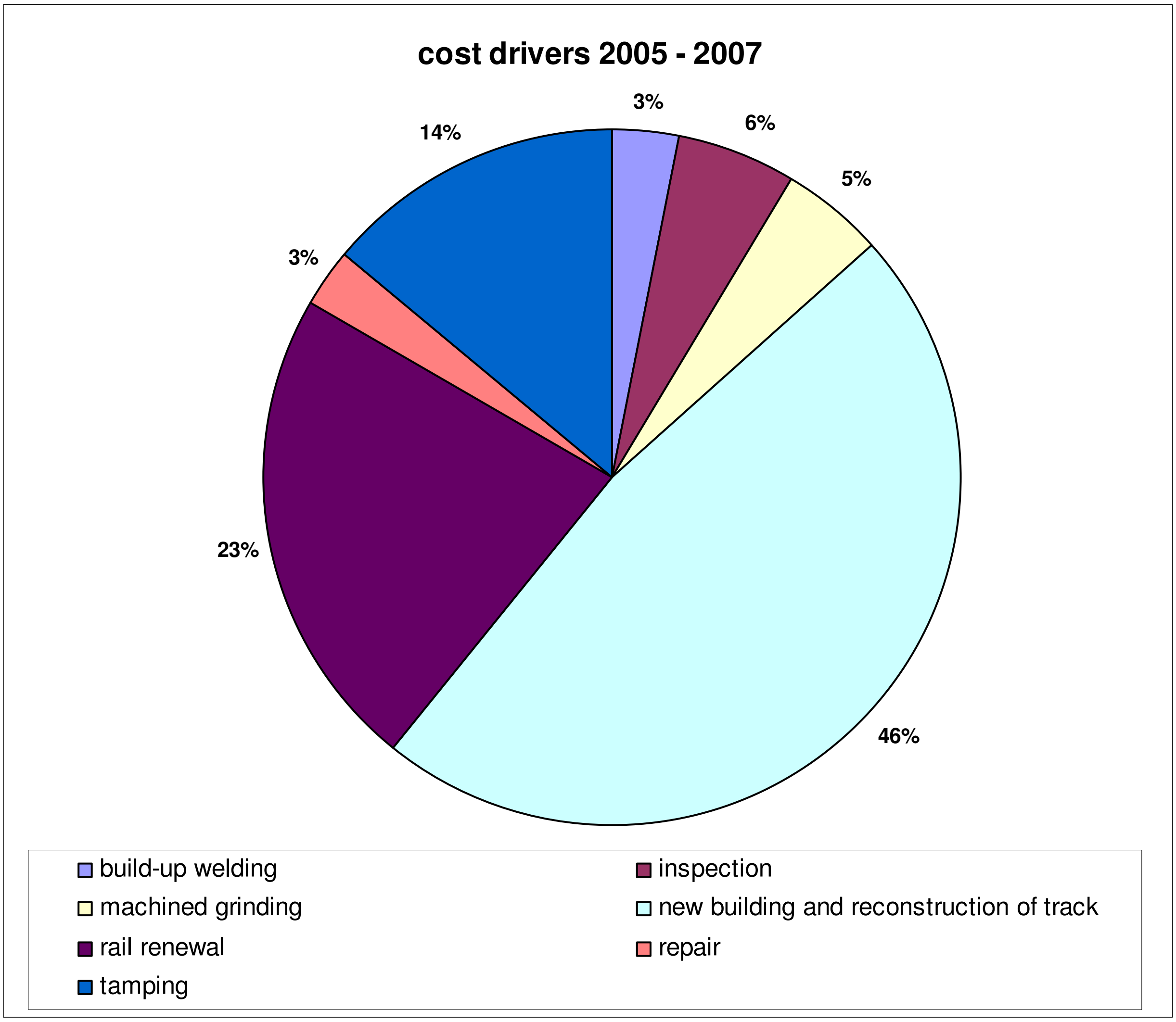


Figure 12: Cost driver distribution (“all other costs” excluded)

Note:
Also the switches and crossings (S&Cs) of site 1 were analysed in detail. But the results are presented in report D3.1.2.

3.7 Track condition: failures and maintenance works -cost drivers

According to the cost analysis, maintenance cost drivers for track construction are:

- Rail renewal
- Rail grinding
- Tamping of main track
- Tamping of switches and crossings (S&C)
- Maintenance of S&C

Rail renewal

Rail renewals have to be done in cases of rail breakage (seldom for DB track site No. 1) and in cases of the rail failures with high damage degree (category 1). The most failures of category 1 on the analysed track are: Belgrospis in the high-speed sections and Head Checks in sections with lower speed.

Grinding

Maintenance work rail grinding can be conducted in following cases:

- preventive (before rail failures occur)
- grinding of new rails
- rail failures of low damage degree
- not acceptable equivalent conicity.

Actual grinding strategy of infrastructure managers in districts along the DB track site 1 is: regularly grinding of new rails and no grinding of old rails – until the rails have to be renewed.

Within the cost analysis it has been noticed that the grinding costs were not constantly distributed over the analysed time: In the year 2005 noticeable less grinding works has been done than in year 2006. ß

Tamping of main track

Under maintenance activity “ballast tamping” can be distinguished between:

- tamping of long track sections, and
- tamping of single track geometry failures (maximal length 15 m).

Tamping machines for main track or universal tamping machines have to be used for tamping of long sections.

Tamping of single track geometry failures can be done using a special single failure tamping machine or with hand-held tamping units. Tamping quality of these two methods is very different. Sustainability of tamping works with hand-held tamping units is very short, because ballast cannot be optimally compacted and can be more damaged than in case of using a tamping machine.

It has been noticed, that there is a large difference in the procedure with single failure correction between different net districts along the analysed track line. Some districts use only hand-held tamping units; the other prefer single failure tamping machine to correct not only single failures, but also for tamping of sections longer than 15m.

According to information from infrastructure managers, tamping of long sections was strongly reduced since the year 2002.

The analysis of the track geometry, bridges, tunnels, expansion joints, switches and maintenance activities shows that most of the tamping activities are related to single disturbances like transitions zones or switches.

Figure 13 shows for a section of DB site 1 from km 189 to km 209 the tamping activities (magenta) and the transition zones (blue). The values are normalized, but the higher the value of tamping, the higher the number of tamping. Each step means one tamping activity at this place.

In this section all tamping activities from 2001 and 2007 are related to the transition zones. In general more than one tamping were carried out only in transition zones.

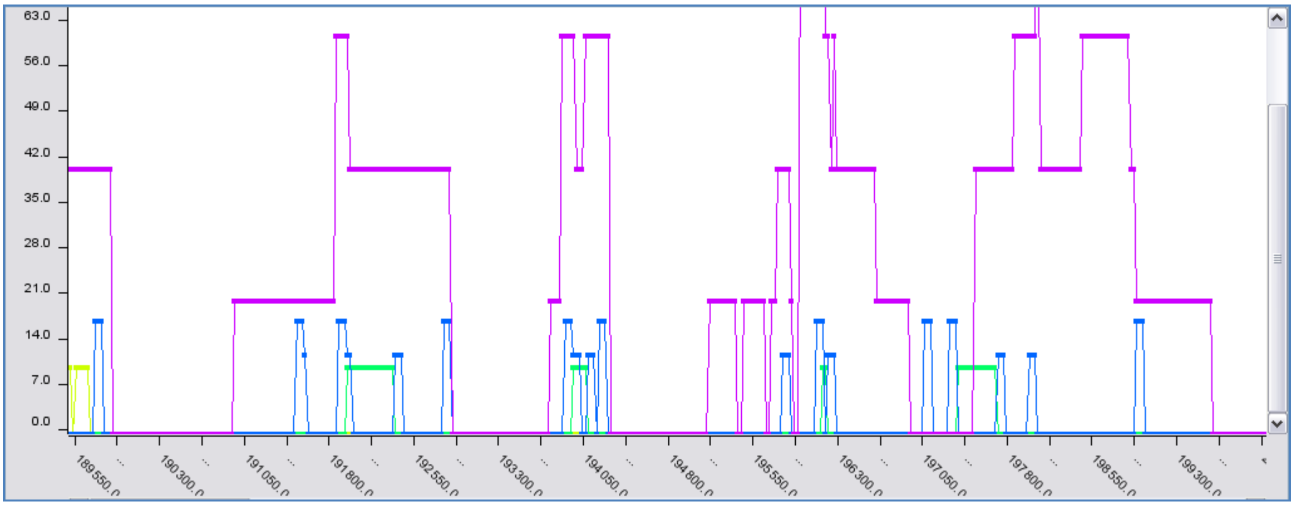


Figure 13: Relation between tamping activities (magenta) and transition zones (blue), section of DB site 1 from km 189 to km 200

In contrast to *Figure 13*, Figure 14 shows another section of the same site where the main tamping activities are not strongly related to transition zones. Especially from km 225 to km 227 where the ballast was tamped twice no transition exist.

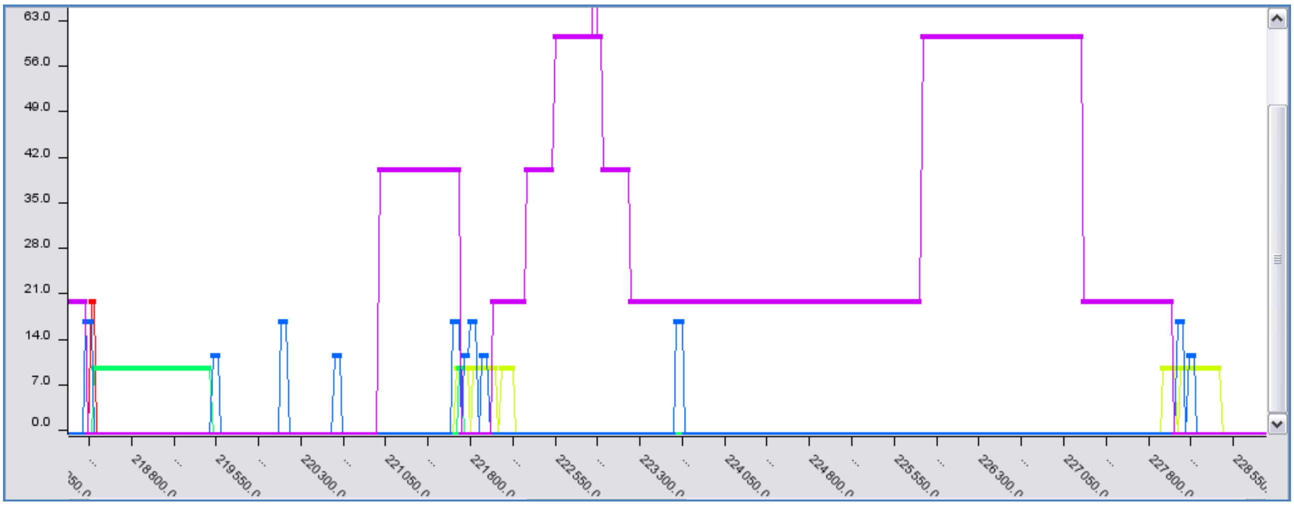


Figure 14: Relation between tamping activities (magenta) and transition zones (blue), section of DB site 1 from km 218 to km 228

Finally Figure 15 shows a section of the same site with a great number of transitions where nearly no tamping activities were carried out in transition zones.

The different results of the three sections clearly point out the problem of a global segmentation and the derivation of maintenance strategies or design strategies from segmentation. The reasons for the different behaviour of similar track sections are unknown and will be currently analysed.

The same results – different long-term behaviour at similar sections - can be found for all failures types like head checks, Belgrospis or short wave length corrugation.

By the time the reasons for the different behaviour are unknown a strategic or global optimisation approach on the basis of "critical" track segments will not lead doubtless to an optimised system regarding the life cycle cost.

By contrast using the sections approach –the sections where currently cost driving failure occurs – for the “local” optimisation of the track can reduce significantly the life cycle costs and lead in either case to a reduction of LCC. The experiences from optimisation lead to an increase knowledge which supports further decisions.

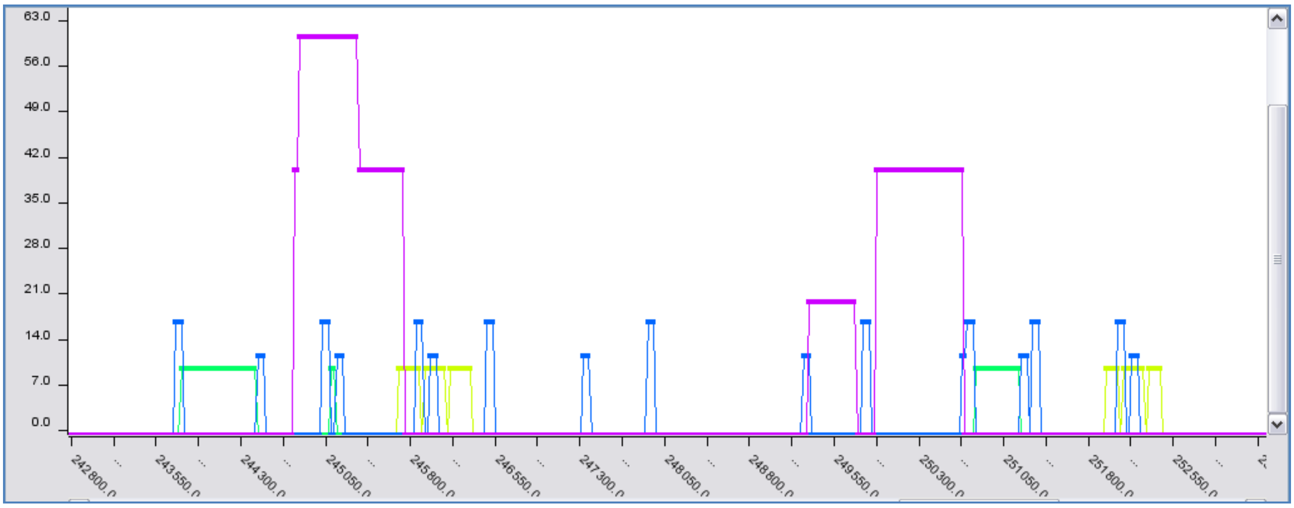


Figure 15: Relation between tamping activities (magenta) and transition zones (blue), section of DB site 1 from km 243 to km 253

Tamping of switches & crossings (S&C)

For tamping of S&C specialised switch tamping machines or universal tamping machines can be used. The average tamping interval over all S&C on the DB track site 1 is 2 years. Some switches have to be tamped once a year. Sustainability of tamping works in switches on the selected high-speed track is generally very bad, because:

- the areas of point operating units cannot be tamped using tamping machines

  (The point operating units (or switch drive rods) are situated directly in the ballast layer and can be tamped only with hand-held tamping units.)
- there are no sleeper connecting plates
- there are still no ballast supporting constructions in a large number of switches

Maintenance of S&C

Maintenance cost drivers of S&C are “switch frog renewal” and “switch blade renewal”. Cost categories “inspection, cleaning and greasing of switches and crossings” and “others” are also cost drivers for S&C.

The average life cycle of switch frog and switch blade on track site No. 1 is about 15 to 20 years. Due to the fact that the track construction is between 18 and 20 years old, a large number of switches need renewal of these elements in the next years.

All failures found on DB track site 1are shown in **Table 8**. The cost driver related failures are marked with bold red colour.

For all cost drivers one or more example sections have been selected. Their short description can be found in chapter 3.9.

Table 8: Catalogue of failures related to maintenance cost drivers on DB track site 1 (cost drivers marked in red)

Rail	Fastening	Pads	Sleepers
Short-wavelenght corrugation	Broken wedge clamp	Worn	Bending failure
Belgrospis	Loose	Split	Shear failure
Headchecks / RCF	Missing	Disintegrated	Bearing failure
Squats		increased Stiffness	Attrition
Long-wavelenght corrugation			Reinforcement corrosion
Side wear			
Fracture			
Other			

Ballast	Subgrade	Drainage	Switches / Crossings
White spots	Diff. Settlements (Transitions)	Blockage	**Rail failure: Headchecks, Belgrospis**
Compacted crumbled ballast	Loss of bearing capacity	Low flow capacity	Fastenings, Pads and Sleepers
Different settlements	Sludge spots		**Ballast**
Loss of stability			**Switch frog**
Reduced drainage capability			**Switch blade**
			Failure of other elements

3.8 Boundary conditions

Boundary conditions describe traffic data on the DB track site 1 and environment data in the region of the selected track.

3.8.1 Traffic data

Traffic data have been collected for the analysed time period 01/2005 – 06/2007 for the following weeks:

- Week No.15 / 2005
- Week No. 43 / 2005
- Week No. 14 / 2006
- Week No. 43 / 2006
- Week No. 16 / 2007

The traffic data is divided in segments between operational points and content:

- km-specification,
- number of load [tonne/week]
- number of trains for :
  - long distance traffic (like for example ICE)

- local traffic
- suburban traffic (S-Bahn)
- freight traffic
- other traffic

The maximal loaded section is app. 4 km long section in direction 1, which has the following data:

- Week No.15 / 2005: max load 367.162 t/week, total number of trains 619
- Week No. 43 / 2005: max load 513.471 t/week, total number of trains 617
- Week No. 14 / 2006: max load 496.826 t/week, total number of trains 579
- Week No. 43 / 2006: max load 497.784 t/week, total number of trains 583
- Week No. 16 / 2007: max load 516.791 t/week, total number of trains 579

Direction of traffic:

- for direction 1: km-upwards
- for direction 2: km-downwards

Max speed varies in different sections.
Max speed on the DB track site 1 is 280 km/h.
Max speed for respective example sections is given in the detailed example data.

3.8.2 Environment data

The following table 9 shows the average temperature, average height of precipitation and average insolation for DB site 1.

Table 9: Environment data for DB track site 1

	average temperature [° C]	average height of precipitation [mm]	average insolation [h]
spring	8 - 9	160 - 170	450 - 500
summer	16 - 17	200 - 240	600 - 650
autumn	8 - 9	160 - 180	250 - 300
Winter	-1 - 0	160 - 180	100 - 150

3.9 Typical sections with failures - cost drivers

Failures which cause maintenance cost drivers on main track of the DB track site 1 are:

- Belgrospis,
- short-wave rail corrugation,
- head checks,
- white spots and
- differential settlements of ballast (mostly in transition areas).

For each failure type one or more typical sections have been selected. Detailed information for all selected example sections - as much information as possible - has been collected: data about track construction elements, subgrade, line routing, traffic data and geometry measurement data. This information was systematically collected especially for further detailed analysis and modelling of maintenance issues in the project InnoTrack.

An overview of the examples for main track is given with **Table 10**. More information can be found in the following sections and in the data files prepared for the InnoTrack data base.

Examples for S&C cost drivers have also been selected and described in the report D3.1.2 of work package 3.1 Switches and Crossings.

Table 10: Overview of the selected example sections

Example	from km	to km
Belgrospi, section 1	197,935	199,955
Belgrospi section 2	199,100	197,955
Short-wave rail corrugation	278,000	281,000
Head check section 1	324,900	325,800
Head check section 2	231,250	229,300
White spot section 1 (bridge)	173,716	175,166
White spot section 2 (transfer line, station)	179,640	179,020
White spot section 3 (transfer line, station)	160,320	160,750
White spot section 4 (bridge counter bearing)	120,412	120,853

3.9.1 Short-wavelength rail corrugation

The selected section is 3 km long with typical short-wavelength rail corrugation on straight line as well as in transition curves (clothoid) and in curves in both directions. The maximum speed in this section is 280 km/h in both directions and the subgrade is made of very stiff soil with protective layer (except one 5m long bridge).

The amplitude of corrugation waves is between 8/100 mm and 10/100 mm. The development of short-wavelength corrugation areas and corrugation wave depth in this section is given through annual rail surface measurements (available measurements for the time period 2001 – 2007).

Railway track line	**DB Site No.1**	
Issue	**Corrugation**	in track sections with high speed (v>200 km/h) in straight line segments as well as in curves, with consequence of rail failures Belgrospi
Directory with data files	**Example_Corrugation**	

Selected example section		
	Direction	1 and 2
	Start km	278
	End km	281

Segments with corrugation	**Segment No.1**		**Segment No.2**		**Segment No. 3**	
	Direction	1	Direction	2	Direction	2
	Start km	278,145	Start km	278,615	Start km	279,300
	End km	280,755	End km	279,215	End km	280,330
	Lenght [m]	2610	Lenght [m]	600	Lenght [m]	1030
	Corrugation Amplitude	10/100 mm	Corrugation Amplitude	8/100 mm	Corrugation Amplitude	8/100 mm

Corrugation Measurements	**Data file**
Direction 1	*Exp_Corrugation_Rail_Surface_Measurements_2001-2007.xls*
Direction 2	
	Notice: Measurements 2001-2007 for selected section

Track construction elements	**Rail**				**Sleeper**			**Rail fastening**		**Pad**		**Ballast**			
Start km - End km	Type	Quality Grade	Profile	Incination	Type	Mean Span	USP	Type	Wegde Clamp	Type	Dynamic Stiffness	Rock	Thickness	E-modulus	UBM
278 - 281	UIC 60	880	E2	1:40	B 70 W	60 cm	none	W14	Skl14	Zw 700	medium	Basalt / Diabas	37 cm	200 MN/m²	none

Notice:
USP under sleeper pad

Notice:
Pad dynamical Stiffness
soft ≤ 100 kN/mm
medium > 100 and ≤ 400 kN/mm
stiff > 400 kN/mm

Notice:
UBM under ballast mat

Subgrade	**Soil**		**Bridge Construction**		**Soil**	
	Direction	1 and 2	Direction	1 and 2	Direction	1 and 2
	Start km	278,000	Start km	280,039	Start km	280,044
	End km	280,039	End km	280,044	End km	281,000
	Lenght	2039 m	Lenght	5 m	Lenght	956 m
	Protective layer	yes	Type	frame structure	Protective layer	yes
	Ev2	very stiff	Material	reinforced concret	Ev2	very stiff

Notice: Ev2 - modulus of static deformation
soft ≤ 60 MN/m²
medium > 60 and < 100 MN/m²
stiff ≥ 100 and < 120 MN/m²
very stiff ≥ 120 MN/m²

Line routing	**Direction 1 (for example)**							
	Element	Type	Start km	End km	Radius [m]	Superelevation [mm]	Gradient [‰]	
	1	straight line	277,526	278,567	0	0	increasing max	3,0
	2	clothoid	278,567	278,843	0 - 5937,5	0 - 75	decreasing max	- 12,5
	3	curve	278,843	280,481	5937,5	75	*Notice:*	
	4	curve	280,481	281,546	5597,65	75	*gradient is bound to direction 1*	
	5	clothoid	281,546	281,821	5597,65 - 0	75 - 0		
	6	straight line	281,821	283,157	0	0		

Data files	
Direction 1	*Exp_Corrugation_Line_Routing_Data_D1.xls*
Direction 2	*Exp_Corrugation_Line_Routing_Data_D2.xls*

Notice: detailed routing data with horizontal position elements, gradients and superelevation (cant) in data files

Traffic data	**Direction of traffic**		**Max speed [km/h]**		**Load [t/week]**	
	Direction 1	km-upwards	Direction 1	280	Direction 1	256452
	Direction 2	km-downwards	Direction 2	280	Direction 2	217422

Data file	
Direction 1	*Exp_Corrugation_Traffic_Data.xls*
Direction 2	

Notice: detailed traffic data with number of trains and load/week in data file - for weeks: 15/2005, 43/2005, 14/2006, 43/2006, 16/2007

Geometry measurements data				
	Diagramms	**Data file**	*Exp_Corrugation_Track_Geometry_Diagramms.ppt*	*Notice: one measurement data set respectively for years 2006 and 2007 for both directions D1 and D2*
	Data	**Data file**	In Directory: *Geometry Measurements Data*	
	Parameter description	**Data file**	*Description_of_Parameter_from_Track_Geometry_Measurements.xls*	*Notice: in the data files are saved only the most important geometry data, not all data channels from track coach measurements*

3.9.2 Belgrospi - section one

The first example section for rail failures Belgrospi is a section, which had rail renewal of both rails (right and left rail) in both directions in autumn 2007. The length of section with rail failures Belgrospi and required rail renewal was 2020 m in direction 1 and 1145 m in direction 2.

The number of rail failures Belgrospi on this section was about 30 for each direction; the failures have been placed in groups (nests) with 3 to 4 single Belgrospi rail failures.

In the middle of the example section a 733m long bridge is situated and on both sides of the bridge there are short transition areas to tunnel constructions. The rail failures Belgrospi has been detected only outside of tunnels, but according to the construction situation the rail renewal had to be done also in the neighbouring first tunnel sections.

Maximal speed of this section is 280 km/h and the line routing consists of two curves with transition curves (clothoid) and short straight line between the curves.

Railway track line	**DB Site No.1**	
Issue	**Belgrospi**	Rail renewal due to rail failures Belgrospi
Directory with data files	**Example_Belgrospi_1**	

Selected example section		
	Direction	1 and 2
	Start km	197.935
	End km	199.955

Segments with Belgrospis	**Segment No.1**		**Segment No.2**	
	Direction	1	Direction	2
	Start km	197.935	Start km	197.995
	End km	199.955	End km	199.100
	Length [m]	2020	Length [m]	1145

Track construction elements	**Rail**				**Sleeper**			**Rail fastening**		**Pad**		**Ballast**			
Start km - End km	Type	Quality Grade	Profile	Inclination	Type	Mean Span	USP	Type	Wegde Clamp	Type	Dynamic Stiffness	Rock	Thickness	E-modulus	UBM
197.935 - 199.955	UIC 60	880	E2	1:40	B 70 W	60 cm	none	W14	Skl14	Zw 700	medium	Basalt	37 cm	200 MN/m²	none

Notice:
USP under sleeper pad

Notice:
Pad dynamical Stiffness
soft ≤ 100 kN/mm
medium > 100 and ≤ 400 kN/mm
stiff > 400 kN/mm

Notice:
UBM under ballast mat

Subgrade	**Tunnel**		**Bridge**		**Tunnel**		**Soil (two short sections)**	
	Direction	1 and 2	Direction	1 and 2	Direction	1 and 2	Direction	1 and 2
	Start km	197.155	Start km	198.127	Start km	199.035	Section 1	km197.993 - km198.127
	End km	197.993	End km	198.860	End km	202.855	Section 2	km198.860 - km199.035
	Lenght	838 m	Lenght	733 m	Lenght	3820 m	Lenght	134 m and 175 m
	Type	flat bottom slab	Type	box girder bridge	Type	flat bottom slab	Protective layer	yes
	Material	reinforced concret	Material	reinforced concret	Material	reinforced concret	Ev2	very stiff

Notice: Ev2 - modulus of static deformation
soft ≤ 60 MN/m²
medium > 60 and < 100 MN/m²
stiff ≥ 100 and < 120 MN/m²
very stiff ≥ 120 MN/m²

Line routing	**Direction 1 (for example)**						**Gradient [‰]**	
	Element	Type	Start km	End km	Radius [m]	Superelevation [mm]		
	1	straight line		197.938	0	0	increasing max	/
	2	clothoid	197.938	198.245	0 - -5102.35	0 - 90	decreasing max	-12,5
	3	curve	198.245	198.493	-5102.35	90		
	4	clothoid	198.493	198.800	-5102.35 - 0	90 - 0		
	5	straight line	198.800	199.172	0	0		
	6	clothoid	199.172	199.479	0 - 5097.65	0 - 90		
	7	curve	199.479	201.434	5097.65	90		

Notice:
gradient is bound to direction 1

Data files	
Direction 1	*Exp_Belgrospi_1_Line_Routing_Data_D1.xls*
Direction 2	*Exp_Belgrospi_1_Line_Routing_Data_D2.xls*

Notice: detailed routing data with horizontal position elements, gradients and superelevation (cant) in data files

Traffic data	**Direction of traffic**		**Max speed [km/h]**		**Load [t/week]**	
	Direction 1	km-upwards	Direction 1	280	Direction 1	457396
	Direction 2	km-downwards	Direction 2	280	Direction 2	406840

Data file	
Direction 1 Direction 2	*Exp_Belgrospi_1_Traffic_Data.xls*

Notice: detailed traffic data with number of trains and load/week in data file - for weeks: 15/2005, 43/2005, 14/2006, 43/2006, 16/2007

Geometry measurements data				
	Diagramms	**Data file**	*Exp_Belgrospi_1_Track_Geometry_Diagramms.ppt*	*Notice: one measurement data set respectively for years 2006 and 2007 for both directions D1 and D2*
	Data	**Data file**	In Directory: *Geometry Measurements Data*	
	Parameter description	**Data file**	*Description_of_Parameter_from_Track_Geometry_Measurements.xls*	*Notice: in the data files are saved only the most important geometry data, not all data channels from track coach measurements*

3.9.3 Belgrospi – section two

The second example section with rail failures Belgrospi is a section without any constructions.

This section is situated in direction 2 directly after the exit of a station, which has a possibility of bifurcation of the track line. Maximal line speed is 280 km/h and the line routing in the area with rail failures Belgrospi contains a curve with radius 5500 m and a suitable transition curve (clothoid).

Railway track line	**DB Site No.1**	
Issue	**Belgrospi**	Rail failures Belgrospi in a section without any constructions
Directory with data files	**Example_Belgrospi_2**	

Selected example section		
	Direction	2
	Start km	301.375
	End km	300.723

Segments with Belgrospi	**Segment No.1**	
	Direction	2
	Start km	301.375
	End km	300.723
	Length [m]	652

Track construction elements	**Rail**				**Sleeper**			**Rail fastening**		**Pad**		**Ballast**			
Start km - End km	Type	Quality Grade	Profile	Inclination	Type	Mean Span	USP	Type	Wegde Clamp	Type	Dynamic Stiffness	Rock	Thickness	E-modulus	UBM
301.375 - 300.723	UIC 60	880	E2	1:40	B 70 W	60 cm	none	W14	Skl14	Zw 700	medium	Basalt / Diabas	37 cm	200 MN/m²	none

Notice:
USP under sleeper pad

Notice:
Pad dynamical Stiffness
soft ≤ 100 kN/mm
medium > 100 and ≤ 400 kN/mm
stiff > 400 kN/mm

Notice:
UBM under ballast mat

Subgrade	**Soil**	
	Direction	2
	Start km	301.375
	End km	300.723
	Length m	652
	Protective layer	yes
	Ev2	very stiff

Notice: Ev2 - modulus of static deformation
soft ≤ 60 MN/m²
medium > 60 and < 100 MN/m²
stiff ≥ 100 and < 120 MN/m²
very stiff ≥ 120 MN/m²

Line routing	**Direction 2**							
	Element	Type	Start km	End km	Radius [m]	Superelevation [mm]	Gradient [‰]	
	1	curve	299.493	300.904	5502		increasing max	1.5
	2	clothoid	300.904	301.190	5502 - 0		decreasing max	
	3	straight line	301.190	303.750	0		*Notice: gradient is bound to direction 1*	

Data files	
Direction 2	*Exp_Belgrospi_2_Line_Routing_Data_D2.xls*

Notice: detailed routing data with horizontal position elements, gradients and superelevation (cant) in data files

Traffic data	**Direction of traffic**		**Max speed [km/h]**		**Load [t/week]**	
	Direction 2	km-downwards	Direction 2	280	Direction 2	254307

Data file	
Direction 2	*Exp_Belgrospi_2_Traffic_Data.xls*

Notice: detailed traffic data with number of trains and load/week in data file - for weeks: 15/2005, 43/2005, 14/2006, 43/2006, 16/2007

Geometry measurements data				
	Diagramms	**Data file**	*Exp_Belgrospi_2_Track_Geometry_Diagramms.ppt*	*Notice: one measurement data set respectively for years 2006 and 2007 for direction D2*
	Data	**Data file**	In Directory: *Geometry Measurements Data*	
	Parameter description	**Data file**	*Description_of_Parameter_from_Track_Geometry_Measurements.xls*	*Notice: in the data files are saved only the most important geometry data, not all data channels from track coach measurements*

3.9.4 Head Checks - section one

This example section is typical section for development of rail failures Head Checks. The section is situated in a curve with radius 1600 m (in tunnel) and its transition curves (clothoid) on neighbouring bridges on both sides of the tunnel in direction 2 of the DB track site 1. The head checks also occur in the tunnel. The maximal speed in this section is 160 km/h.

The rail failures Head Checks were the reason for maintenance activities on this section in the past and the rail has again achieved a damage degree, which requires a rail grinding within the next year.

Railway track line	**DB Site No.1**	
Issue	**Headchecks**	Rail failures Head Checks in a curve with radius 1600m; low damage degree (depth 0,5 mm)
Directory with data files	**Example_Headchecks_1**	

Selected example section		
	Direction	2
	Start km	324.900
	End km	325.800

Segments with Head Checks	**Segment No.1**	
	Direction	2
	Start km	324.900
	End km	325.800
	Length [m]	900

Track construction elements	**Rail**				**Sleeper**			**Rail fastening**		**Pad**		**Ballast**			
Start km - End km	Type	Quality Grade	Profile	Inclination	Type	Mean Span	USP	Type	Wegde Clamp	Type	Dynamic Stiffness	Rock	Thickness	E-modulus	UBM
324.900 - 325.800	UIC 60	880	E2	1:40	B 70 W	60 cm	none	W14	Skl14	Zw 700	medium	Basalt / Diabas	37 cm	200 MN/m^2	none

Notice:
USP under sleeper pad

Notice:
Pad dynamical Stiffness
soft ≤ 100 kN/mm
medium > 100 and ≤ 400 kN/mm
stiff > 400 kN/mm

Notice:
UBM under ballast mat

Subgrade	**Bridge Construction 1**		**Tunnel 2**		**Bridge Construction 3**		**Soil in two short sections 1/2 & 2/3**	
	Direction	2	Direction	2	Direction	2	Direction	2
	Start km	324.842	Start km	325.042	Start km	325.637	Section 1/2	km324.970 - km325.042
	End km	324.970	End km	325.621	End km	325.791	Section 2/3	km325.621 - km325.637
	Lenght	128 m	Lenght	579 m	Lenght	154 m	Lenght	72 m and 16 m
	Type	box girder bridge	Type	bottom plate	Type	box girder bridge	Protective layer	yes
	Material	reinforced concret	Material	jetcrete	Material	reinforced concret	Ev2	very stiff

Notice: Ev2 - modulus of static deformation
soft ≤ 60 MN/m^2
medium > 60 and < 100 MN/m^2
stiff ≥ 100 and < 120 MN/m^2
very stiff ≥ 120 MN/m^2

Line routing	**Direction 2**							
	Element	Type	Start km	End km	Radius [m]	Superelevation [mm]	Gradient [‰]	
	1	clothoid	324.778	325.048	0 - -1600	0 - 95	increasing max	5,0
	2	curve	325.048	325.669	-1600	95	decreasing max	-12,5
	3	clothoid	325.669	325.939	-1600 - 0	95 - 0	*Notice: gradient is bound to direction 1*	

Data files	
Direction 2	*Exp_Headchecks_1_Line_Routing_Data_D2.xls*

Notice: detailed routing data with horizontal position elements, gradients and superelevation (cant) in data files

Traffic data	**Direction of traffic**		**Max speed [km/h]**		**Load [t/week]**	
	Direction 2	km-downwards	Direction 2	160	Direction 2	390902

Data file	
Direction 2	*Exp_Headchecks_1_Traffic_Data.xls*

Notice: detailed traffic data with number of trains and load/week in data file - for weeks: 15/2005, 43/2005, 14/2006, 43/2006, 16/2007

Geometry measurements data				
	Diagramms	**Data file**	*Exp_Headchecks_1_Track_Geometry_Diagramms.ppt*	*Notice: one measurement data set respectively for years 2006 and 2007 for direction D2*
	Data	**Data file**	In Directory: *Geometry Measurements Data*	
	Parameter description	**Data file**	*Description_of_Parameter_from_Track_Geometry_Measurements.xls*	*Notice: in the data files are saved only the most important geometry data, not all data channels from track coach measurements*

3.9.5 Head Check - section two

The second example section had rail renewal of both rails due to Head Check rail failures in year 2007. This section is situated in direction 2 in a tunnel and the line routing consists of a curve with radius 2500 m and its neighbouring transition curves (clothoid). Along this section trains increase the speed from 100 km/h up to 220 km/h. The gradient in direction 2 is increasing and relative large 11,23 ‰. The head checks also occur in the tunnel.

Railway track line	**DB Site No.1**	
Issue	**Headchecks**	Rail renewal due to rail failures Head Checks in a curve with radius 2500m, acceleration section with large increasing gradient in tunnel
Directory with data files	**Example_Headchecks_2**	

Selected example section		
	Direction	2
	Start km	231.250
	End km	229.300

Segments with Head Checks	**Segment No.1**	
	Direction	2
	Start km	231.250
	End km	229.300
	Length [m]	1950

Track construction elements	**Rail**				**Sleeper**			**Rail fastening**		**Pad**		**Ballast**			
Start km - End km	Type	Quality Grade	Profile	Inclination	Type	Mean Span	USP	Type	Wegde Clamp	Type	Dynamic Stiffness	Rock	Thickness	E-modulus	UBM
231.250 - 229.300	UIC 60	880	E2	1:40	B 70 W	60 cm	none	W14	Skl14	Zw 700	medium	Basalt / Diabas	37 cm	200 MN/m²	none

Notice:
USP under sleeper pad

Notice:
Pad dynamical Stiffness
soft ≤ 100 kN/mm
medium > 100 and ≤ 400 kN/mm
stiff > 400 kN/mm

Notice:
UBM under ballast mat

Subgrade	**Soil**		**Tunnel**	
	Direction	2	Direction	2
	km	231.250	Start km	231.050
	km	231.050	End km	223.675
	Length	200 m	Length	7375 m
	Protective layer	yes	Type	flat bottom slab
	Ev2	very stiff	Material	reinforced concret

Notice: Ev2 - modulus of static deformation
soft ≤ 60 MN/m²
medium > 60 and < 100 MN/m²
stiff ≥ 100 and < 120 MN/m²
very stiff ≥ 120 MN/m²

Line routing	**Direction 2**						
	Element	Type	Start km	End km	Radius [m]	Superelevation [mm]	Gradient [‰]
	1	curve	222.867	227.632	7002.35	65	increasing max /
	2	clothoid	227.632	227.855	7002.35 - 0	65 - 0	decreasing max - 11.22
	3	straight line	227.855	229.749	0	0	*Notice:*
	4	clothoid	229.749	229.940	0 - 2502.35	0 - 115	*gradient is bound to direction 1*
	5	curve	229.940	231.028	2502.35	115	
	6	clothoid	231.028	231.219	2502.35 - 0	115 - 0	
	7	straight line	231.219	232.184	0	0	

Data files	
Direction 2	*Exp_Headchecks_2_Line_Routing_Data_D2.xls*

Notice: detailed routing data with horizontal position elements, gradients and superelevation (cant) in data files

Traffic data	**Direction of traffic**		**Max speed [km/h]**		**Load [t/week]**	
	Direction 2	km-downwards	Direction 2	220	Direction 2	422238

Data file	
Direction 2	*Exp_Headchecks_2_Traffic_Data.xls*

Notice: detailed traffic data with number of trains and load/week in data file - for weeks: 15/2005, 43/2005, 14/2006, 43/2006, 16/2007

Geometry measurements data				
	Diagramms	**Data file**	*Exp_Headchecks_2_Track_Geometry_Diagramms.ppt*	*Notice: one measurement data set respectively for years 2006 and 2007 for direction D2*
	Data	**Data file**	In Directory: *Geometry Measurements Data*	
	Parameter description	**Data file**	*Description_of_Parameter_from_Track_Geometry_Measurements.xls*	*Notice: in the data files are saved only the most important geometry data, not all data channels from track coach measurements*

3.9.6 White spots in ballast on a bridge

The following example describes a bridge with 24 white spots in the ballast in direction 1. The white spots occur mostly in joints areas of bridge piers. The bridge has two expansion joints with under ballast mat in each direction (on both ends of the bridge). The sleeper type on the bridge is B 93.1.

Maximal speed on the bridge is 280 km/h. The line routing consists of a curve with radius 7000 m and the suitable transition curve (clothoid).

Railway track line	**DB Site No.1**	
Issue	**White Spot**	24 white spots in ballast on the bridge (in joints areas of bridge piers)
Directory with data files	**Example_White_Spots_1**	

Selected example section		
	Direction	1
	Start km	173.716
	End km	175.174

Segments with white spots	**Segment No.1**	
	Direction	1
	Start km	173.716
	End km	175.174
	Length [m]	1458

Track construction elements	**Rail**				**Sleeper**			**Rail fastening**		**Pad**		**Ballast**			
Start km - End km	Type	Quality Grade	Profile	Inclination	Type	Mean Span	USP	Type	Wegde Clamp	Type	Dynamic Stiffness	Rock	Thickness	E-modulus	UBM
173.716 - 175.174	UIC 60	880	E2 *)	1:40	B 93.1	60 cm	none	W14	Skl14	Zw 700	medium	Basalt	37 cm	200 MN/m²	none *)

*)since 2004 before grinding E1

Notice:
USP under sleeper pad

Notice:
Pad dynamical Stiffness
soft ≤ 100 kN/mm
medium > 100 and ≤ 400 kN/mm
stiff > 400 kN/mm

Notice:
UBM under ballast mat

*) under 2 expansion joints UBM

Subgrade	**Soil**		**Bridge Construction**		**Soil**	
	Direction	1	Direction	1	Direction	1
	Start km	173.468	Start km	173.707	Start km	175.174
	End km	173.707	End km	175.174	End km	175.348
	Length m	239	Length m	1467	Length m	174
	Protective layer	yes	Type	box girder bridge	Protective layer	yes
	Ev2	very stiff	Material	prestressed concret	Ev2	very stiff

Notice: Ev2 - modulus of static deformation
soft ≤ 60 MN/m²
medium > 60 and < 100 MN/m²
stiff ≥ 100 and < 120 MN/m²
very stiff ≥ 120 MN/m²

Line routing	**Direction 1**							
	Element	Type	Start km	End km	Radius [m]	Superelevation [mm]	Gradient [‰]	
	1	curve	172.546	174.948	6997.650	65	increasing max	12,5
	2	clothoid	174.948	175.171	6997.65 - 0	65 - 0	decreasing max	/

Notice:
gradient is bound to direction 1

Data files	
Direction 1	*Exp_White_Spot1_Line_Routing_Data_D1.xls*

Notice: detailed routing data with horizontal position elements, gradients and superelevation (cant) in data files

Traffic data	**Direction of traffic**		**Max speed [km/h]**		**Load [t/week]**	
	Direction 1	km-upwards	Direction 1	280	Direction 1	457259

Data file	
Direction 1	*Exp_White_Spots_1_Traffic_Data.xls*

Notice: detailed traffic data with number of trains and load/week in data file - for weeks: 15/2005, 43/2005, 14/2006, 43/2006, 16/2007

Geometry measurements data				
	Diagramms	**Data file**	*Exp_White_Spots_1_Track_Geometry_Diagramms.ppt*	*Notice: one measurement data set respectively for years 2006 and 2007 for direction D1*
	Data	**Data file**	In Directory: *Geometry Measurements Data*	
	Parameter description	**Data file**	*Description_of_Parameter_from_Track_Geometry_Measurements.xls*	*Notice: in the data files are saved only the most important geometry data, not all data channels from track coach measurements*

3.9.7 White spots in ballast on a transfer line to station- section one

White spots occur frequently in station areas, which are not the stop stations for the high-speed traffic of the track site 1, but can be used as transfer line for changing of track routes.

The selected example section is a transfer line station with four white spots in the direction 2.

The line speed of the track site 1 in this section is also 280 km/h. The line routing is a straight line with increasing gradient of 12,5 ‰ in the direction 2.

Railway track line	**DB Site No.1**	
Issue	**White Spot**	White spots in ballast in a station, which has been used as transfer line; v_max for the track site 1 is here 280 km/h
Directory with data files	**Example_White_Spots_2**	

Selected example section	**Direction**	2
	Start km	179.640
	End km	179.020

Segments with white spots	**Segment No.1**	
	Direction	2
	Start km	179.640
	End km	179.020
	Length [m]	620

Track construction elements	**Rail**				**Sleeper**			**Rail fastening**		**Pad**		**Ballast**			
Start km - End km	Type	Quality Grade	Profile	Inclination	Type	Mean Span	USP	Type	Wegde Clamp	Type	Dynamic Stiffness	Rock	Thickness	E-modulus	UBM
179.640 - 179.020	UIC 60	880	E2	1:40	B70	60 cm	none	W14	Skl14	Zw 700	medium	Diabas	37 cm	200 MN/m²	none

Notice:
USP under sleeper pad

Notice:
Pad dynamical Stiffness
soft ≤ 100 kN/mm
medium > 100 and ≤ 400 kN/mm
stiff > 400 kN/mm

Notice:
UBM under ballast mat

Subgrade	**Soil**	
	Direction	2
	Start km	179.640
	End km	179.020
	Length m	620
	Protective layer	yes
	Ev2	very stiff

Notice: Ev2 - modulus of static deformation
soft ≤ 60 MN/m²
medium > 60 and < 100 MN/m²
stiff ≥ 100 and < 120 MN/m²
very stiff ≥ 120 MN/m²

Line routing	**Direction 2**							
	Element	Type	Start km	End km	Radius [m]	Superelevation [mm]	Gradient [‰]	
	1	straight line	178.665	180.469	0	0	increasing max	12,5
							decreasing max	/

Notice:
gradient is bound to direction 1

Data files	
Direction 2	*Exp_White_Spots_2_Line_Routing_Data_D2.xls*

Notice: detailed routing data with horizontal position elements, gradients and superelevation (cant) in data files

Traffic data	**Direction of traffic**		**Max speed [km/h]**		**Load [t/week]**	
	Direction 2	km-downwards	Direction 2	280	Direction 2	407126

Data file	
Direction 2	*Exp_White_Spots_2_Traffic_Data.xls*

Notice: detailed traffic data with number of trains and load/week in data file - for weeks: 15/2005, 43/2005, 14/2006, 43/2006, 16/2007

Geometry measurements data	**Diagramms**	**Data file**	*Exp_White_Spots_2_Track_Geometry_Diagramms.ppt*	*Notice: one measurement data set respectively for years 2006 and 2007 for direction D2*
	Data	**Data file**	In Directory: *Geometry Measurements Data*	
	Parameter description	**Data file**	*Description_of_Parameter_from_Track_Geometry_Measurements.xls*	*Notice: in the data files are saved only the most important geometry data, not all data channels from track coach measurements*

3.9.8 White spots in ballast on a transfer line to station – section two

The following example section is the second example for transfer line (station) with white spots in ballast.

The selected section needs frequent ballast tamping due to track geometry faults and white spots in ballast. There are currently four white spots only in direction 2 of the selected section.

The maximal section speed is 280 km/h. The line routing is straight line with a small decreasing gradient 1,089 ‰ in direction 2.

Railway track line	**DB Site No.1**	
Issue	**White Spot**	White spots in ballast in a station, which has been used as transfer line; v_max for the track site 1 is here 280 km/h
Directory with data files	**Example_White_Spots_3**	

Selected example section		
	Direction	2
	Start km	160.32
	End km	160.75

Segments with white spots	**Segment No.1**	
	Direction	2
	Start km	160.32
	End km	160.75
	Length [m]	430

Track construction elements	**Rail**				**Sleeper**			**Rail fastening**		**Pad**		**Ballast**			
Start km - End km	Type	Quality Grade	Profile	Inclination	Type	Mean Span	USP	Type	Wegde Clamp	Type	Dynamic Stiffness	Rock	Thickness	E-modulus	UBM
160.750 - 160.320	UIC 60	880	E2	1:40	B70	60 cm	none	W14	Skl14	Zw 700	medium	Basalt	37 cm	200 MN/m²	none

Notice:
USP under sleeper pad

Notice:
Pad dynamical Stiffness
soft ≤ 100 kN/mm
medium > 100 and ≤ 400 kN/mm
stiff > 400 kN/mm

Notice:
UBM under ballast mat

Subgrade	**Soil**	
	Direction	2
	Start km	160.320
	End km	160.750
	Length m	430
	Protective layer	yes
	Ev2	very stiff

Notice: Ev2 - modulus of static deformation
soft ≤ 60 MN/m²
medium > 60 and < 100 MN/m²
stiff ≥ 100 and < 120 MN/m²
very stiff ≥ 120 MN/m²

Line routing	**Direction 2**							
	Element	Type	Start km	End km	Radius [m]	Superelevation [mm]	Gradient [‰]	
	1	straight line	157.84113	161.787	0	0	increasing max	1.08957
							decreasing max	/

Notice:
gradient is bound to direction 1

Data files	
Direction 2	*Exp_White_Spots_3_Line_Routing_Data_D2.xls*

Notice: detailed routing data with horizontal position elements, gradients and superelevation (cant) in data files

Traffic data	**Direction of traffic**		**Max speed [km/h]**		**Load [t/week]**	
	Direction 2	km-downwards	Direction 2	280	Direction 2	407125

Data file	
Direction 2	*Exp_White_Spots_3_Traffic_Data.xls*

Notice: detailed traffic data with number of trains and load/week in data file - for weeks: 15/2005, 43/2005, 14/2006, 43/2006, 16/2007

Geometry measurements data				
	Diagramms	**Data file**	*Exp_White_Spots_3_Track_Geometry_Diagramms.ppt*	*Notice: one measurement data set respectively for years 2006 and 2007 for direction D2*
	Data	**Data file**	In Directory: *Geometry Measurements Data*	
	Parameter description	**Data file**	*Description_of_Parameter_from_Track_Geometry_Measurements.xls*	*Notice: in the data files are saved only the most important geometry data, not all data channels from track coach measurements*

3.9.9 White spots in ballast on a bridge counter bearing

The last example describes a bridge with white spot on counter bearing construction only on one side of the bridge. The bridge has embedded under ballast mats since the beginning of operation of the track site.

On the opposite side of the white spot in ballast, the bridge has one expansion joint in each direction.

The white spot occurs direct on the counter bearing construction of the bridge on the side without expansion joint in the transition area to the neighbouring soil and tunnel construction. The length of the white spot is about 8.5 m (14 sleepers). The maximal speed line the section is 280 km/h.

Railway track line	**DB Site No.1**	
Issue	**White Spot**	White spot in ballast on a bridge counter bearing (on the side without expansion joint)
Directory with data files	**Example_White_Spots_4**	

Selected example section		
	Direction	2
	Start km	120.412
	End km	120.853

Segments with white spots	**Segment No.1**	
	Direction	2
	Position km	120.850
	Length [m]	8.5
	Number of sleepers	14

Track construction elements	**Rail**				**Sleeper**			**Rail fastening**		**Pad**		**Ballast**			
Start km - End km	Type	Quality Grade	Profile	Inclination	Type	Mean Span	USP	Type	Wegde Clamp	Type	Dynamic Stiffness	Rock	Thickness	E-modulus	UBM
120.412 - 120.853	UIC 60	880	E2*)	1:40	B70	60 cm	none	W14	Skl14	Zw 700	medium	Basalt	37 cm	200 MN/m²	yes
			*)E1 since 2004 E2		*Notice:* *USP under sleeper pad*					*Notice:* *Pad dynamical Stiffness* *soft ≤ 100 kN/mm* *medium > 100 and ≤ 400 kN/mm* *stiff > 400 kN/mm*		*Notice:* *UBM under ballast mat*			

Subgrade	**Bridge Construction**		**Soil**		**Tunnel**	
	Direction	2	Direction	2	Direction	2
	Start km	120.412	Start km	120.853	Start km	120.974
	End km	120.853	End km	120.974	End km	
	Length m	441	Length m	121	Length m	long tunnel
	Type	box girder bridge	Protective layer	yes	Type	flat bottom slab
	Material	composite bridge	Ev2	very stiff	Material	reinforced concret

Notice: Ev2 - modulus of static deformation
soft ≤ 60 MN/m²
medium > 60 and < 100 MN/m²
stiff ≥ 100 and < 120 MN/m²
very stiff ≥ 120 MN/m²

Line routing	**Direction 2**							
	Element	Type	Start km	End km	Radius [m]	Superelevation [mm]	Gradient [‰]	
	1	straight line	116.803	120.778	0	0	increasing max	0
	2	clothoid	120.778	121.001	0 - 7004.7	0 - 65	decreasing max	0
							Notice: *gradient is bound to direction 1*	

Data files	
Direction 2	*Exp_White_Spots_4_Line_Routing_Data_D2.xls*

Notice: detailed routing data with horizontal position elements, gradients and superelevation (cant) in data files

Traffic data	**Direction of traffic**		**Max speed [km/h]**		**Load [t/week]**	
	Direction 2	km-downwards	Direction 2	280	Direction 2	428914

Data file	
Direction 2	*Exp_White_Spots_4_Traffic_Data.xls*

Notice: detailed traffic data with number of trains and load/week in data file - for weeks: 15/2005, 43/2005, 14/2006, 43/2006, 16/2007

Geometry measurements data				
	Diagramms	**Data file**	*Exp_White_Spots_4_Track_Geometry_Diagramms.ppt*	*Notice: one measurement data set respectively for years 2006 and 2007 for direction D2*
	Data	**Data file**	In Directory: *Geometry Measurements Data*	
	Parameter description	**Data file**	*Description_of_Parameter_from_Track_Geometry_Measurements.xls*	*Notice: in the data files are saved only the most important geometry data, not all data channels from track coach measurements*

4. Conclusions

Conclusions will be written, when all reports from the different IM’s are available.